APPENDIX G

NORTHERN SPOTTED OWL

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CHARTS

TABLES

Northern Spotted Owl Dispersal Assessment Overview

This Appendix describes the modeling process and steps used to create the Ecosystem Management Decision Support- Dispersal Assessment Model, used for comparing projections of dispersal habitat for Northern Spotted Owls under the three modeled Alternatives.

Appendix G is comprised of four parts:

1. EMDS-DAT Stand Model Development
2. EMDS-DAT Reported Stand Scores by SOMU
3. EMDS-DAT Stand scores of +0.5 and above
4. EMDS-DAT Landscape Model Development

1: EMDS-DAT Stand Model

The methodology DNR has developed for assessing habitat for juvenile spotted owl dispersal consists of two distinct stages. In the first stage, each individual forest stand is evaluated to determine the level to which it supports dispersal, and then in the second stage the spatial configuration of these stand evaluations across the landscape is assessed.

For the first stage, DNR elected to use the "Ecosystem Management Decision Support" software (EMDS) (Reynolds 1999, www.institute.redlands.edu/emds/) as a framework for the analysis because it provides a relatively simple and flexible tool for developing ecological assessment models linked to geographic information systems (GIS).

The model structures and parameters were developed by a group of wildlife biologists (herein after referred to as the "Science Team") during a two-day workshop held Jan. 9-10, 2007 and follow-up communications. These structures and parameters were then used to develop the EMDS computer models by a modeling team, composed of DNR staff and consultants.

Table G1-1. EMDS-DAT Development Participants

Science Team	Title	Agency
Joseph Buchanan	Owl Biologist	Washington Department of Fish and Wildlife
Dr. Scott Horton	Owl Biologist	Washington Department of Natural Resources
Heather McPherson	Wildlife Ecologist	Washington Department of Natural Resources
Dr. Teodora Minkova	Owl Biologist	Washington Department of Natural Resources
Stan Sovern	Owl Biologist	U.S. Forest Service, Cle Elum, OR
Modeling Team		
Angus Brodie	Data Stewardship Assistant	Washington Department of Natural Resources
Heather McPherson	Wildlife Ecologist	Washington Department of Natural Resources
Lowell Dickson	Environmental Analyst	Washington Department of Natural Resources
Dr. Joshua Halofsky	Landscape Ecologist	Washington Department of Natural Resources
Dr. Sean Gordon	Research Forester	U.S. Forest Service, Portland, OR

	(decision support specialist)	
Dr. Keith Reynolds	Research Forester (decision support specialist)	U.S. Forest Service, Corvallis, OR

An Overview of Ecosystem Management Decision Support (EMDS)

There are many approaches to modeling and evaluating habitat. DNR selected a fairly simple, flexible, and intuitive approach using software produced by the Forest Service called the Ecosystem Management Decision Support System or EMDS. EMDS is an ArcGIS extension which provides methods for evaluating a number of different habitat indicators (e.g. canopy cover, snags, etc.) and then combining these evaluations into an overall habitat assessment score (Reynolds 1999, Reynolds et al 2000). The same model can then be applied to different landscapes, or at multiple points in time to compare management scenarios.

EMDS, unlike using strict threshold definitions, evaluates the “truth” of an assertion by using the fuzzy set theory of mathematics (FuzzyTech 1999, Zadeh 1992). The use of fuzzy curves to evaluate conditions removes the rigid yes/no thresholds of binary evaluations and provides a more realistic approach of evaluating habitat (Reynolds 1999).

Model Structures

The basic idea behind EMDS models (and most habitat suitability indices or HSI's) is to take a number of measurable indicators and then add them up into an overall assessment score. The model structure provides an outline of what is added up and how. HSI models are commonly expressed as mathematical equations or more qualitative habitat matrices. EMDS uses elements of both these approaches by providing a number of basic building blocks which can do quantitative or qualitative evaluations. These building blocks are generally arranged in a hierarchical network, which decomposes the overall goal of the assessment into finer and finer sub-components, until measurable indicators are reached. In describing these models, the word “indicator” is used to refer to a measurable aspect of habitat and “topic” is used to describe a group of indicators combined as a particular theme. The Science Team identified three basic needs of dispersing owls: foraging, roosting, and movement. A separate model was built to assess habitat in relation to each of these needs (displayed in Figures G-1 to G-3).

Figure G-1. EMDS-DAT Foraging Model

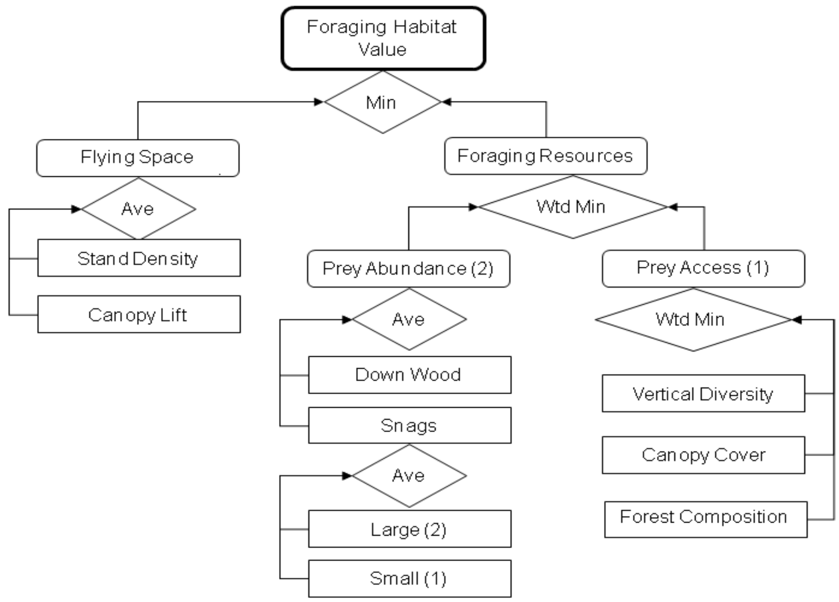


Figure G- 2. EMDS-DAT Roosting Model

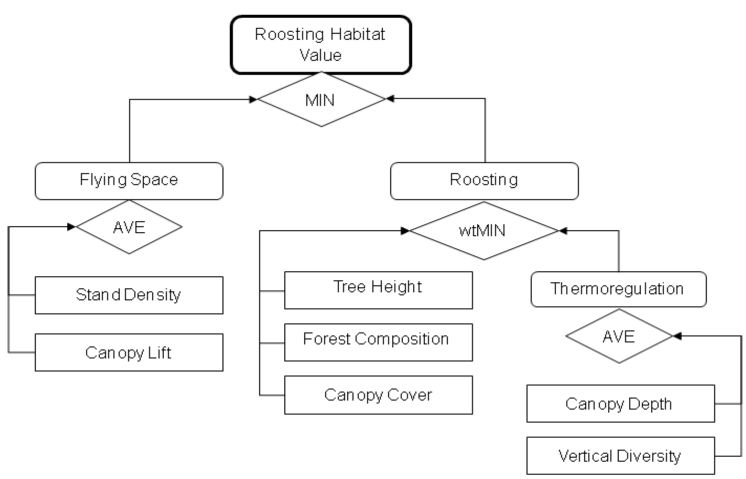
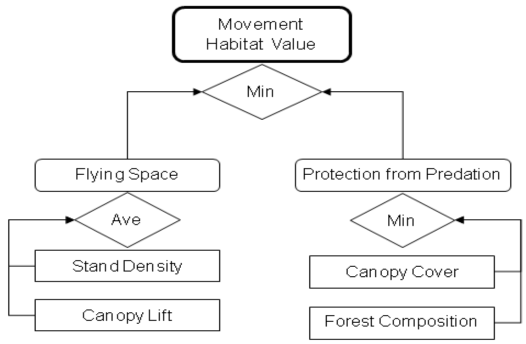


Figure G-3. EMDS-DAT Movement Model



Weights
Some model elements may be deemed by experts as more important for owls than others. This difference can be captured in the model by assigning weights to an indicator. All indicators start with a default weight of one. If one indicator is twice as important as another, it is assigned a weight of two (or alternatively the less important one assigned a weight of 0.5). The scope of a particular weight is limited to the place where two or more indicators are combined into a higher level topic in the hierarchy (e.g. the combination of large and small snags in Figure G-1). Grouping indicators into topics, as just discussed, usually makes weighting easier. In Figures G-1 to G-3, weights are indicated in parentheses following the topic/indicator name.

Combination Operators
EMDS provides a number of "operators" for use in combining individual topic/indicator values to the next higher node in the hierarchy. Operators are simple mathematical concepts. The following three operators are currently used in the EMDS-DAT models:

AVE (Average): the average of the sub-nodes is passed up the model (good sub-node scores can partially compensate for poor sub-scores and vice-versa)

MIN (Minimum): the minimum of the sub-nodes is passed up the model (akin to a limiting factor type analysis) wtMIN (Weighted Minimum): if any one of the scores is –1, then –1 is passed up to the condition score, otherwise it passes up a result weighted toward the lowest sub-node score. This operator provides an option in between the Average and Minimum operators. The precise function is: wtMIN(subnodes) = min(subnodes) + [average(subnodes) - min(subnodes)]*[min(subnodes)+1] / 2

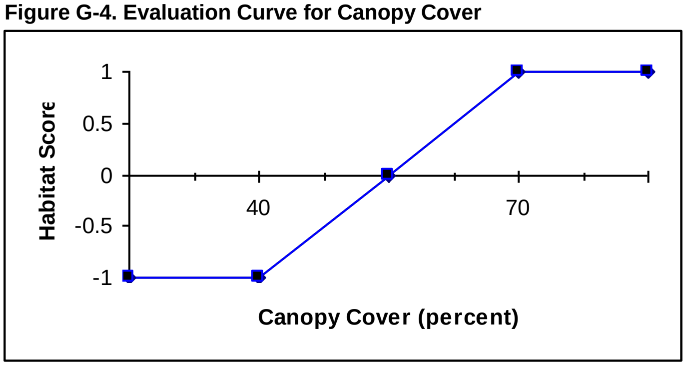
Evaluation Functions

In order to combine indicators, they first must be converted (normalized) to a common scale. In EMDS, this is done by setting up evaluation criteria, which are standards to which a particular indicator value is compared to decide whether it reflects positively or negatively on the assessment objective. The result of this comparison is a normalized evaluation score between "-1" and "+1". The criteria can be hard and fast (as they often are in habitat matrix approaches), e.g. canopy cover > 70% is acceptable (evaluated score = +1) and < 70% is not acceptable (-1), but one of the advantages of EMDS is that it allows more flexible criteria that produce a finer gradation of results.

An example using canopy cover is presented below. The horizontal axis represents the indicator measure and the vertical axis represents the resulting evaluated (and normalized) score. The line connecting the squares represents the evaluation function. What it says is that at a canopy cover of ≤ 40% the habitat value is -1 (not at all indicative of suitable dispersal habitat) and at 70% and above the habitat is rated +1 (fully functional). Canopy covers between 40 and 70% receive an intermediate score based on a linear interpolation between the two (55% would produce a score of 0

Values for the inflection points on the evaluation criteria curves are derived from the most reliable available source, from peer-reviewed scientific publications, analysis of existing data sets, and best professional judgment. Since the literature and data on owl dispersal are limited and often not focused precisely on the indicators chosen for the models, the professional judgment of the Science Team was often used interpret, synthesize and estimate the criteria. Evaluation criteria for each indicator are detailed in the following section.

Figure G-4. Evaluation Curve for Canopy Cover



Context Switches

Context switches use input data to change when and how to evaluate other indicators. For example, many old growth stands have canopy cover of < 70%, so the Science Team decided to allow the +1 threshold for canopy cover to go down to 60% if the stand structure resembled old growth. The context indicator used is stand development stage, and the rule is when stand development stage > 4 (either Niche Diversification or Fully Functional stages) then the +1 threshold is set to 60%.

Stand Level Model Descriptions

The rest of this section follows the model structures from the top down, and describes the essential features of each branch or node. As an example, the Roosting Habitat topic node contains a description of the rationale for choosing its sub-nodes and the aggregator used to combine them. Indicator node descriptions use the following format:

Rationale: Brief rationale for choosing the indicator

Literature: A very brief summary of the literature on this indicator, especially as related to evaluation criteria.

Measure: How the indicator is measured (e.g. average height of the forty tallest trees)

Data Source: Where the data for the indicator comes from.

Criteria: Evaluation criteria (i.e. threshold values used to score the indicator from -1 to +1) and rationale.

Roosting model

Model Structure Rationale

Tree height and forest composition are seen as the most fundamental indicators for identifying roosting habitat and are therefore evaluated at the top level. Three canopy measures are combined to form the thermoregulation/protection from predators input to roosting habitat.

Model Aggregator Rationale

Tree height, forest composition and the protection from predation branch can partially compensate for one another, so they are combined with an AVERAGE operator.

Tree Height

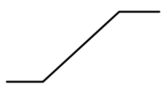
Rationale: NSO requires a certain tree height for adequate roosting opportunities

Literature: SAG (1993 p. 57) cites studies where the average height of roost trees was between 85-110 ft.

Measure: Average height of the forty largest diameter trees.

Data Source: Height as recorded in the FRIS inventory system and projected by FVS.

Criteria: Roost trees are not necessarily the largest trees in the stand, so our model places the average roost tree height (85') near the center of the evaluation curve.

Indicator:	**Tree Height**		
Shape	Eval. Score	Thresholds	Units
			
	+1	120	Feet
	-1	50	Feet

Forest Composition

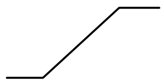
Rationale: A certain percentage of conifers in the forest composition is important for thermoregulation and cover from predators.

Literature: Thomas et al (1990) noted that NSO are virtually always located in conifer-dominated forest types. SAG (1993) found a definition of mixed conifer stands as 30-70% conifers. In contrast, Herter et al. (2002) found 5-8% of roost sites on lands not classified as habitat by DNR, and these were primarily areas of high hardwood canopy cover (< 70% conifer).

Measure: Percent of stand basal area in conifers (trees > 3.5" dbh)

Data Source: Calculated from FVS tree lists

Criteria: SAG (1993) and the HCP (WADNR 1997) used a minimum definition of 30%. The Science Team judged this as too low, especially in winter when deciduous trees provide little cover.

Indicator:	Forest Composition		
Shape	Eval. Score	Thresholds	Units
			
	+1	90	% conifer
	-1	50	% conifer

Thermoregulation and Protection from Predators
Model Structure Rationale

The DNR workshop found no data to distinguish elements important for thermoregulation from those important for protection from predators, so they are represented in one model structure. Canopy depth and vertical diversity are used to measure the amount and diversity of vertical roosting choices, primarily important for thermoregulation. These vertical measures are then combined with canopy closure, which provides protection from predation by great horned owls and thermal cover.

Model Aggregator Rationale

Canopy Depth and Vertical Diversity are partially compensatory, so they are combined with the AVERAGE operator. However, these vertical measures are not seen as compensatory with the more horizontal Canopy Cover measure, so these are combined using a MINIMUM operator.

Canopy Closure

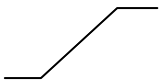
Rationale: Provides protection from predation and thermal cover. Great horned owls hunt in more open areas and are the greatest predator threat to the NSO.

Literature: SAG (1993) cited average values of heavily used stands from 60-90%.

Measure: FVS-generated canopy cover is the only measure for all stands over time. A reliable crosswalk between closure (measured from below, typically used in wildlife studies) and cover (measured from above, generated by remote sensing and forest models) would help refine the criteria but has not been found.

Data Source: The EMDS model uses an FVS generated estimate of canopy cover for all trees > 3.5” dbh (assuming smaller trees would not provide cover at typical roosting heights).

Criteria: Canopy closure on old-growth stands can often fall below 70%, so the +1 value was lowered to 60% if a stand was classified as beyond the stand development stage 4. Based on expert judgment at 2/8/07 DNR workshop and subsequent follow-up.

Indicator:	**Canopy closure**		
Shape	Eval. Score	Thresholds	Units
	+1	70	%
	+1	60 (SDS > 4)	%
	-1	40	%

Canopy Depth

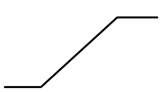
Rationale: Deeper canopies provide a larger thermal buffer (more insulation) and greater predation avoidance possibilities.

Literature: No published studies have measure canopy depth relative to NSO use; however, North et al. (1999) found a greater foliage volume in high use stands.

Measure: Average height of the dominant stratum minus the average height to live crown (lift) of the lowest stratum (Appendix 1 – Canopy Layers describes how FVS identifies strata). If the lift measure is < 20', it is set to 20' (assuming that canopy below 20' is generally not useful for roosting).

Data Source: Not measured as part of the field inventory. FVS models the average tree height and height-to-base-of-live-crown (canopy lift) for each identified vertical stratum or layer. Canopy depth is defined as the difference between these two measurements, for the tallest identified stratum.

Criteria: Based on expert judgment at 2/8/07 DNR workshop.

Indicator:	**Canopy Depth**		
Shape	Eval. Score	Thresholds	Units
			
	+1	65	Feet
	-1	30	Feet

Vertical Diversity

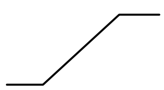
Rationale: A greater diversity of tree heights provides more thermal microhabitats for roosting.

Literature: North (1999) and Carey et al. (1992) found vertical diversity (measured using the Berger-Parker index - BPI) to be significantly associated with owl use. SAG (1993) recommended use of the BPI and set suggested criteria values. Herter et al. (2002) found variation (SD) in tree diameter to be significantly different in roosting (7.2 in.) versus random sites (6.4 in).

Measure: Berger-Parker Index as described in North (1999): trees assigned to 7 classes by height (converting meters to feet: 6.6-13.1 ft; 13.1-26.2; 26.2-52.5; 52.5-105; 105-157.5; 157.5-210; >210 ft) then BPI = total # trees / # trees in most common height class.

Data Source: BPI calculated from FVS projected data, calculated as described above.

Criteria: Based on SAG (1993 p. 105), "…a BPI score < 2.2 generally would indicate low vertical height diversity, and a score > 2.7 should be considered optimal."

Indicator:	**Vertical Diversity**		
Shape	Eval. Score	Thresholds	Units
			
	+1	2.7	BPI
	-1	2.2	

Foraging model
Model Structure Rationale

The quality of habitat for NSO foraging is determined by the abundance of prey species, the accessibility of prey to owl predation, and the protection provided to the NSO from its own predators. The importance of snags and down wood (related to prey abundance) is the best documented factor, followed by accessibility and protection, so these aggregates are weighted accordingly (Prey Abundance 50%, Prey Access 30%, Protection from Predation 20%).

Model Aggregator Rationale

These attributes can partially compensate for each other in determining habitat quality, so they are combined using the AVERAGE operator.

Prey Abundance

Model Structure Rationale

Abundance of prey species for the NSO has primarily been associated with the quantities of snags, down wood, and food sources in an area.

Model Aggregator Rationale

These attributes can partially compensate for each other in determining habitat quality, so they are combined using the AVERAGE operator.

Snags

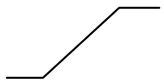
Rationale: Flying squirrels are the principal prey species of NSO in Western Washington, and they mainly den in cavities in snags and live trees. Large snags (as defined by SAG 1993) are more important, but the group believes smaller snags also have value.

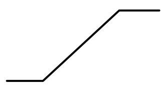
Literature: SAG (1993) cites unpublished data (Carey) illustrating that flying squirrels only reach high abundance in areas with more than two 20" dbh snags per acre. Carey (1995) recommends retaining all large snags (>50 cm / 20” dbh) up to 20 snags/ha (8 snags/acre). The HCP set criteria of 3 snags or cavity trees per acre of 20"+ dbh. North et al. (1999), looking at principally old-growth stands in W. Washington, found that snag volume greater than 142.1 cubic m/ha was correlated with an increase in foraging use and that 70 % of the snag volume came from snags >70 cm (28 in) DBH.

Measure: Snags per acre in two size classes: large (> 20” dbh & >16' ht) and medium (15-20” dbh & >10’ ht).

Data Source: Snags are modeled using the Fire & Fuels extension of FVS. In this model snags decay (2 classes: hard and soft) and fall (90% within 25 years).

Criteria: Following Carey (1995), 8 snags/acre was set as the upper threshold, no snags was set as the lower threshold, and based on the HCP, 3 snags/acre was set as the midpoint.

Indicator:	Large Snags (>20” dbh & >16’ height)		
Shape	Eval. Score	Thresholds	Units
			
	+1	8	# / acre
	0	3	
	-1	0	

Indicator:	Small Snags (15-20” dbh & >10’ height)		
Shape	Eval. Score	Thresholds	Units
			
	+1	8	# / acre
	0	3	
	-1	0	

Down wood

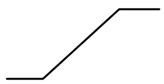
Rationale: Provides living space, movement, and cover for prey.

Literature: The HCP set an expected value of 5%, but cited it as a management hypothesis based on estimate of 15% needed to maintain full small mammal populations (Carey and Johnson 1995). Herter et al. (2002) actually found less down wood at roost sites than random locations and discussed the hypothesis that owls select habitat according to prey accessibility in addition to prey abundance.

Measure: Volume in cubic feet for pieces >4" diameter is the measure in the inventory. DNR has cross-walked cubic feet to the percent cover measure commonly used in the wildlife literature using a linear equation (5% cover = 2400 ft^3, 10% = 4800ft^3, etc).

Data Source: Numbers are modeled using the Fire & Fuels (FFE) extension of FVS. FFE calculates weights, not volumes, so weights of all pieces > 3" diameter are converted into cubic volume. No minimum piece length has been applied.

Criteria: The upper threshold was set to the median value for old stands found in Spies and Franklin (1991). A 5% cover value (= 2400 ft^3) was seen as a minimum needed to maintain adequate populations (so set to a model value of 0).

Indicator:	Down wood (volume)		
Shape	Eval. Score	Thresholds	Units
	+1	5700	Cu. Ft/ac
	0	2,400	Cu. Ft/ac
	-1	0	Cu. Ft/ac

Prey Access

Model Structure Rationale

NSO access to prey is influenced by the availability of a variety of perching heights and a variety of conditions within the stand. Hunting can be impeded by an overly dense overstory and/or understory.

Model Aggregator Rationale

These attributes can partially compensate for each other in determining habitat quality, so they are combined using the AVERAGE operator.

Vertical Diversity

Review: (see Roosting)

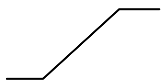
Rationale: A greater diversity of tree heights provides more options for perch heights.

Literature: (see Roosting)

Measure: Berger-Parker Index (see Roosting)

Data Source: (see Roosting)

Criteria: (same as for Roosting)

Indicator:	Vertical Diversity		
Shape	Eval. Score	Thresholds	Units
			
	+1	2.7	BPI
	-1	2.2	

Stem Density

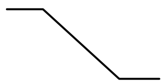
Rationale: If a stand is too dense, it is difficult for owls to forage in.

Literature: Owls need a canopy that is open enough to allow owls to fly within and beneath it (Thomas et al. 1990). The literature has not looked at stand density from a movement-only perspective. Instead, it has been combined with the canopy closure concept to produce a density range that includes enough trees to provide cover but not so many as to be over-dense. SAG (1993) settled on 115-280 tpa by summarizing a variety of studies on intensively used stands: Allen et al. (1989) found 190-210 tpa 4"+, North found 152 tpa 2"+, and Hicks (unpubl.) found 196 tpa 4"+. Beak Consultants (1993) set the Murray Pacific HCP guidelines at between 130-300 tpa of DBH 10"+.

Measure: Trees per acre > 2" dbh (which have an average height ~15' for DNR stands). Higher diameter limit were considered (i.e. starting at 4, 7 or 10" DBH, ~30-70' height) but would potentially miss overly dense stands composed of smaller trees.

Data Source: An FVS variable is used to count all trees ≥ 2" DBH.

Criteria: Given that the lower density thresholds in the literature appear to have been set for the purpose of "cover" rather than "flying space", the model does not use a lower threshold here (a lack of trees does not impede foraging or movement). Further, canopy layers or vertical diversity may affect flying space: a multi-layered or vertically diverse stand may accommodate more stems and still provide reasonable flying space. To reflect this idea, the model increases the maximum TPA thresholds by 100 for each identified canopy layer beyond 1 (as calculated by FVS, ranging from 1 to 3).

Indicator:	**Stem Density (> 2” dbh)**		
Shape	Eval. Score	Thresholds*	Units
	+1	1 Layer: 300 2 Layers: 400 3 Layers: 500	TPA
	-1	1 Layer: 500 2 Layers: 600 3 Layers: 700	TPA

**** Different thresholds correspond to whether the stand has 1, 2, or 3 canopy layers.***

Protection from Predation

Model Structure Rationale

Canopy cover is a reasonable predictor of protection from NSO predation by great horned owls. In the wintertime, the amount of conifers in the stand is the primary determinant of cover and is therefore also included.

Model Aggregator Rationale

In this context, canopy cover and forest composition do not compensate for one another since they are used to represent different seasons of the year. Therefore, they are combined with a MINIMUM operator.

Canopy Closure

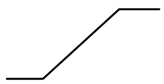
Rationale: Provides protection from predation. Great horned owls hunt in more open areas and are the greatest predator threat to the NSO (Forsman et al. 2002).

Literature: (see Roosting)

Measure: (see Roosting)

Data Source: (see Roosting)

Criteria:

Indicator:	Canopy Closure		
Shape	Eval. Score	Thresholds	Units
			
	+1	70	%
	-1	40	%

Forest Composition

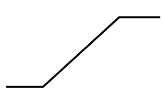
Rationale: Loss of hardwood leaf cover during the winter months increases the vulnerability of the NSO to predation by great horned owls.

Literature: Thomas et al (1990) say that NSO are virtually always located in conifer-dominated forest types. SAG (1993) used a definition of mixed conifer stands as 30-70% conifers.

Measure: (see Roosting)

Data Source: (see Roosting)

Criteria: Lack of conifers is not as great a risk as posed by the more general openness measure of canopy cover, so the lower bound for the model score is set to zero instead of 1 (i.e. hardwood dominated stands still have positive value).

Indicator:	Forest Composition		
Shape	Eval. Score	Thresholds	Units
			
	+1	50	% BA conifer
	0	30	% BA conifer

Movement Model

Model Structure Rationale

The ability of owls to move through a stand is primarily determined by adequate flying space under the canopy and sufficient cover for protection from predators.

Model Aggregator Rationale

Flying Space and Protection from Predation are combined with the MINIMUM operator because both elements are needed and cannot substitute for one another.

Flying Space

Structure Rationale

The ability of owls to fly through a stand is determined primarily by the density of the stand and the amount of flying space available under the canopy.

Model Aggregator Rationale

Stand density and canopy lift partially compensatory, i.e. a dense stand may be better if it has sufficient lift and vice-versa, therefore the AVERAGE of the two determines the suitability of the stand.

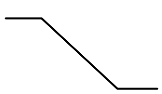
Stand Density

Rationale: If a stand is too dense, it is difficult for owls to fly through.

Literature: See Foraging

Measure: See Foraging

Data Source: See Foraging

Criteria: See Foraging**Indicator:**	**Stem Density (> 2” dbh)**		
Shape	Eval. Score	Thresholds	Units
	+1	1 Layer: 300 2 Layers: 400 3 Layers: 500	TPA
	-1	1 Layer: 500 2 Layers: 600 3 Layers: 700	TPA

Canopy Lift

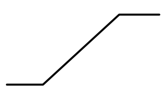
Rationale: Owls need flying space under the canopy.

Literature: Murray Pacific HCP (Beak Consultants Inc. 1993) set a minimum threshold of 20 ft. below canopy (beyond an assumed 10’ shrub layer).

Measure: Space below the canopy (including an assumed 10 ft. tall shrub layer) of dominant and codominant trees.

Data Source: DNR’s FRIS inventory does not contain crown information. The FVS ‘Strclass’ keyword calculates the average height to the base of live crown for each identified stratum. The model uses the height to crown base of the top stratum identified for a stand.

Criteria: The 30’ Murray Pacific HCP value (20’ + 10’ shrubs) was seen as an absolute minimum necessary (-1 threshold) with the value increasing to an upper threshold of 55’.

Indicator:	**Canopy Lift**		
Shape	Eval. Score	Thresholds	Units
			
	+1	55	feet
	-1	30	feet

Protection from Predators

Model Structure Rationale

Canopy cover is the best predictor of protection from NSO predation by great horned owls. In the wintertime, the amount of conifers in the stand is the primary determinant of cover and so is also included.

Model Aggregator Rationale

In this context, canopy cover and forest composition do not compensate for one another, since they are used to represent different seasons of the year. Therefore, they are combined with a MINIMUM operator.

Canopy Closure

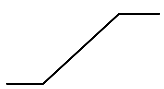
Rationale: Provides protection from predation. Great horned owls hunt in more open areas and are the greatest predator threat to the NSO.

Literature: SAG (1993) cited average values of heavily used stands from 60-90%.

Measure: (see Roosting)

Data Source: (see Roosting)

Criteria: The lower evaluation criterion is less stringent than for foraging (30% vs. 40%) because the NSO needs less canopy cover for moving through a stand.

Indicator:	**Canopy Closure**		
Shape	Eval. Score	Thresholds	Units
			
	+1	70	%
	-1	30	%

Forest Composition

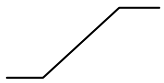
Rationale: Loss of hardwood leaf cover during the winter months increases the vulnerability of the NSO to predation by great horned owls.

Literature: Thomas et al (1990) state that NSO are frequently located in conifer-dominated forest types. SAG (1993) used a definition of mixed conifer stands as 30-70% conifers.

Measure: (see Roosting)

Data Source: (see Roosting)

Criteria: Lack of conifers is not as great a risk as posed by the more general openness measure of canopy cover, so the lower bound for the model score is set to zero.

Indicator:	**Forest Composition**		
Shape	Eval. Score	Thresholds	Units
			
	+1	50	% BA conifer
	0	30	% BA conifer

REFERENCES

Allen, H. L.; Dixon, K. R.; Knutson, K. L. 1989. Cooperative administrative study to monitor spotted owl management areas in national forests in Washington. Washington Department of Wildlife. Olympia, Washington.

Beak Consultants Inc. 1993. Habitat conservation plan for the northern spotted owl on timberlands owned by the Murray Pacific Corporation. Murray Pacific Corporation. Tacoma, WA.

Carey, Andrew B., Scott P. Horton, Brian L. Biswell 1992. Northern Spotted Owls: influence of prey base and landscape character. Ecological Monographs 62 (2): 223-250.

Carey, A. B.; Johnson, M. L. 1995. Small mammals in managed, naturally young, and old-growth forests. Ecological Applications 5:336-352.

Fiala, A.C.S., S.L. Garman, and A.N. Gray. 2006. Comparison of five canopy cover estimation techniques in the western Oregon Cascades. Forest Ecology and Management 232:188-197.

Forsman, E.D., R.G. Anthony, J.A. Reid, P.J. Loschl, S.G. Sovern, M. Taylor, B.L. Biswell, A. Ellingson, E.C. Meslow, G.S. Miller, K.A. Swindle, J.A. Thrailkill, F.F. Wagner, and D.E. Seaman. 2002. Natal and breeding dispersal of northern spotted owls. Wildlife Monographs 149:35.

Herter, D.R., L.L. Hicks, H.C. Stabins, J.J. Millspaugh, A.J. Stabins, and L.D. Melampy.2002. Roost site characteristics of northern spotted owls in the nonbreeding season in central Washington. Forest Science 48(2):437-446.

Hicks, L.L.; Stabins, H. 1995. Spotted owl habitat descriptions for Plum Creek’s Cascades Habitat Conservation Plan. Technical Report No. 4. Plum Creek Timber Company. Seattle, WA, USA.

Hanson, E.; Hays, D.; Hicks, L.; Young, L.; Buchanan, J. 1993. Spotted owl habitat in Washington: a report to the Washington Forest Practices Board. Washington Forest Practices Board Spotted Owl Advisory Group. Olympia, Washington.

Horton, Scott and Steve Wetzel. 2003. Structure and Composition of Spotted Owl Nesting, Roosting, and Foraging Habitat in the Klickitat District. Washington State Department of Natural Resources. Olympia, Washington.

North, M. P. 1993. Stand structure and truffle abundance associated with the northern spotted owl. Ph.D. dissertation, University of Washington. Seattle, WA.

North, M.P., J.F. Franklin, A.B. Carey, E.D. Forsman, and Tom Hamer 1999. Forest Stand Structure of the Northern Spotted Owl's Foraging Habitat. Forest Science, Vol. 45, No 4.

Thomas A. Spies and Jerry F. Franklin. 1991. The Structure of Natural Young, Mature, and Old-Growth Douglas-Fir Forests in Oregon and Washington. In: Wildlife and Vegetation of Unmanaged Douglas-Fir Forests. General Technical Report PNW-GTR-285.

Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Meslow, B. R. Noon, and J. Verner. 1990. A conservation strategy for the Northern Spotted Owl. Report of the Interagency Scientific

Committee to Address the Conservation of the Northern Spotted Owl. U.S. Department of Agriculture Forest Service, Portland, Oregon.

WADNR. 1997. Final Habitat Conservation Plan. Washington State Department of Natural Resources. Olympia, Washington.

WaDNR. 2005. Definition and inventory of old growth forests on DNR-managed state lands. Washington State Department of Natural Resources. Olympia, Washington.

2: Model Results: EMDS-DAT Stand Scores by SOMU

The EMDS-Data Assessment Tool (EMDS-DAT) was used to evaluate three aspects of habitat condition (foraging, roosting, and movement) for each stand in each time period. These habitat scores are calculated separately on a standardized, continuous range from -1 to +1.

The following tables summarize the scores for each Spotted Owl Management Unit (SOMU) by grouping the continuous scores into ranges, referred to here as habitat classes, as described in Table G2-1 below. Tables G2-2 to G2-5 details the number of acres in each habitat class by SOMU, alternative and time period.

Table G2-1 Habitat Classes Key

Habitat Class	EMDS Score	Interpretation
0	-1	No support
1	-0.99 to -0.5	Very weak support
2	-0.49 to 0	Weak support
3	0 to 0.49	Moderate support
4	0.5 to 0.99	Strong support
5	+1	Full support

Table G2-2. Acres by Foraging Habitat Class (Frg Cls) for Each SOMU Over 10 Decades

			PERIOD									
SOMU	**Alt**	**Frg Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ASHFORD	A	0	3,636	3,575	3,401	2,655	801	913	470	970	1,307	1,760
		1	86	22	210	686	1,250	397	304	691	147	56
		2	623	543	510	572	1,590	759	943	233	199	744
		3	2,469	1,613	1,422	1,518	1,555	3,525	3,606	2,442	2,461	1,160
		4	752	1,813	2,023	2,135	2,370	1,972	2,243	3,231	3,453	3,846
	B	0	3,636	3,609	3,208	2,170	1,587	1,322	1,181	1,312	1,287	1,237
		1	86	20	389	1,332	1,349	1,026	298	445	418	1,297
		2	623	493	331	411	432	478	1,123	971	1,118	622
		3	2,469	1,562	1,525	1,281	1,228	1,912	1,815	1,625	1,366	976
		4	752	1,882	2,113	2,371	2,970	2,828	3,149	3,213	3,378	3,434
	C	0	3,636	3,629	3,471	2,782	1,312	2,172	2,087	1,154	1,340	1,280
		1	86	20	231	687	1,235	516	376	521	521	891
		2	623	456	260	378	1,083	467	645	1,276	1,425	1,314
		3	2,469	1,588	1,446	1,218	1,024	1,784	1,383	1,471	1,316	1,239
		4	752	1,873	2,157	2,502	2,912	2,627	3,074	3,145	2,965	2,843

			PERIOD									
SOMU	**Alt**	**Frg Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
BIG CATT	A	0	3,147	2,774	1,652	1,374	387	395	214	747	1,082	1,464
		1	1,183	586	1,017	683	1,151	397	414	482	145	102
		2	1,167	1,670	1,539	1,276	1,115	820	598	350	387	352
		3	1,500	1,852	2,134	2,621	2,297	3,217	3,392	2,241	1,704	1,280
		4	85	201	740	1,129	2,132	2,253	2,465	3,262	3,764	3,885
	B	0	3,147	2,813	1,550	1,269	649	668	811	910	730	580
		1	1,183	522	1,012	544	921	336	130	195	415	326
		2	1,167	1,630	1,040	732	809	394	284	182	302	570
		3	1,500	1,996	2,386	2,765	1,514	1,907	1,655	1,392	849	751
		4	85	121	1,094	1,772	3,189	3,778	4,202	4,403	4,787	4,856
	C	0	3,147	2,662	1,641	1,820	1,170	1,292	1,268	957	519	723
		1	1,183	731	775	424	920	431	225	672	620	578
		2	1,167	1,818	1,505	915	876	461	534	529	962	655
		3	1,500	1,798	2,951	3,038	1,266	1,548	2,071	1,087	1,096	1,174
		4	85	74	210	885	2,850	3,350	2,984	3,837	3,886	3,952

			PERIOD									
SOMU	Alt	Frg Cls	1	2	3	4	5	6	7	8	9	10
BUSY WILD	A	0	5,830	5,944	5,176	4,854	1,490	3,662	1,301	1,597	3,074	3,546
		1	605	418	925	556	3,002	413	428	2,665	244	454
		2	1,820	1,511	1,506	1,389	1,381	812	2,671	594	758	1,032
		3	3,983	3,840	3,759	4,140	4,296	5,651	5,605	3,988	3,885	2,600
		4	2,202	2,728	3,076	3,501	4,273	3,904	4,436	5,597	6,481	6,810
	B	0	5,830	5,913	4,850	4,399	1,824	1,731	3,602	3,075	3,249	3,383
		1	605	239	1,098	1,148	3,472	2,944	774	1,313	706	843
		2	1,820	1,540	1,417	935	695	411	534	542	872	825
		3	3,983	3,700	3,348	3,584	2,488	3,215	2,530	2,223	2,337	2,167
		4	2,202	3,050	3,729	4,376	5,963	6,141	7,002	7,288	7,277	7,224
	C	0	5,830	5,958	4,913	5,181	1,902	3,953	4,114	3,200	3,590	3,494
		1	605	241	1,101	689	3,069	1,010	743	1,542	556	937
		2	1,820	1,615	1,317	822	1,160	468	599	587	1,129	923
		3	3,983	3,600	3,343	3,237	2,471	3,175	2,301	2,016	2,440	2,538
		4	2,202	3,028	3,768	4,513	5,840	5,836	6,684	7,096	6,726	6,549

			PERIOD									
SOMU	**Alt**	**Frg Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
GRASS MOUNTAIN	A	0	9,236	8,630	7,228	5,527	3,611	2,462	1,687	2,095	3,164	3,252
		1	1,340	641	1,745	2,805	2,353	2,204	1,677	1,580	631	962
		2	2,182	2,343	1,400	1,261	1,613	2,948	2,614	1,045	1,568	1,438
		3	2,943	3,716	3,863	3,466	4,036	4,405	5,946	6,242	4,558	3,947
		4	1,765	2,137	3,230	4,407	5,853	5,447	5,542	6,504	7,544	7,866
	B	0	9,236	8,634	7,085	5,544	4,765	3,057	2,833	2,221	1,852	2,290
		1	1,340	638	1,709	2,927	1,552	2,144	1,126	1,934	2,515	835
		2	2,182	2,336	1,447	832	1,480	1,642	1,522	616	319	2,099
		3	2,943	3,662	4,164	3,732	3,353	3,327	4,325	4,341	3,957	3,340
		4	1,765	2,195	3,062	4,431	6,316	7,296	7,659	8,355	8,823	8,903
	C	0	9,236	8,654	7,326	5,527	3,901	3,028	3,384	3,251	3,149	3,039
		1	1,340	684	1,693	2,984	2,302	2,296	1,237	1,262	1,780	1,403
		2	2,182	2,464	1,638	1,307	1,990	2,134	1,879	914	847	1,237
		3	2,943	3,736	4,447	4,076	3,963	4,041	4,656	4,580	3,763	3,772
		4	1,765	1,928	2,362	3,572	5,310	5,968	6,309	7,458	7,927	8,015

			PERIOD									
SOMU	**Alt**	**Frg Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MINERAL CREEK	A	0	2,853	2,776	2,162	1,239	268	17	17	65	576	1,133
		1	238	87	639	927	943	244	22	137	22	18
		2	211	168	205	781	1,217	918	384	78	180	208
		3	768	1,128	794	549	1,024	2,160	2,491	1,731	632	352
		4	312	225	583	887	931	1,045	1,468	2,373	2,973	2,672
	B	0	2,853	2,776	2,140	1,218	752	505	66	151	716	718
		1	238	83	636	941	942	247	456	466	487	477
		2	211	142	123	503	99	204	265	34		28
		3	768	1,054	779	672	1,202	1,705	1,565	1,644	1,177	1,186
		4	312	328	705	1,050	1,389	1,722	2,030	2,087	2,002	1,973
	C	0	2,853	2,825	2,226	1,691	1,167	1,081	714	255	399	549
		1	238	42	508	918	942	500	700	1,253	1,102	900
		2	211	178	178	54	254	302	322	146	222	242
		3	768	1,149	1,134	806	738	1,102	1,244	1,273	1,295	1,274
		4	312	189	338	914	1,281	1,398	1,403	1,455	1,366	1,418

			PERIOD									
SOMU	**Alt**	**Frg Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
NORTH FORK GREEN	A	0	3,065	2,990	3,054	3,084	833	511	349	448	1,168	1,828
		1	1,121	440	296	396	2,226	712	613	586	157	54
		2	1,467	1,296	706	423	986	2,049	336	167	192	572
		3	1,529	2,355	2,343	2,051	1,288	1,756	3,627	3,034	1,497	1,317
		4	248	348	1,031	1,476	2,097	2,402	2,505	3,195	4,416	3,658
	B	0	3,065	2,947	2,865	2,665	810	518	399	483	1,785	1,495
		1	1,121	433	247	489	2,100	585	540	476	240	362
		2	1,467	1,307	775	435	324	446	77	115	113	330
		3	1,529	2,295	2,356	2,262	1,291	2,429	2,730	2,468	1,435	1,357
		4	248	448	1,186	1,581	2,905	3,453	3,684	3,887	3,857	3,887
	C	0	3,065	2,935	3,069	3,049	981	2,018	1,859	460	670	740
		1	1,121	435	321	421	2,243	554	637	1,920	1,488	1,465
		2	1,467	1,433	841	476	440	396	136	205	377	287
		3	1,529	2,312	2,555	2,313	1,309	1,258	1,609	1,416	1,612	1,610
		4	248	314	644	1,172	2,457	3,204	3,189	3,428	3,285	3,329

			PERIOD									
SOMU	**Alt**	**Frg Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
NORTH FORK MINERAL	A	0	3,567	2,932	2,214	2,036	1,075	879	345	1,278	1,956	1,940
		1	2,049	787	1,285	1,034	1,312	655	854	1,005	519	197
		2	3,079	3,984	2,677	2,237	1,222	1,542	1,443	559	490	649
		3	3,897	4,841	5,389	5,036	4,999	5,352	5,768	4,306	2,764	2,402
		4	286	333	1,312	2,534	4,269	4,449	4,469	5,729	7,149	7,690
	B	0	3,567	2,891	1,713	1,743	1,099	859	967	567	690	827
		1	2,049	684	1,147	500	944	616	191	702	752	139
		2	3,079	3,519	1,882	1,631	831	329	413	231	312	1,058
		3	3,897	5,434	6,355	5,647	3,584	2,628	1,937	1,883	1,320	1,152
		4	286	350	1,781	3,357	6,420	8,447	9,370	9,494	9,804	9,701
	C	0	3,567	2,818	2,255	2,918	2,518	2,062	1,773	1,044	868	1,408
		1	2,049	838	1,125	606	959	1,092	1,032	1,801	1,138	582
		2	3,079	3,932	2,207	1,380	1,303	801	699	889	1,749	1,467
		3	3,897	5,127	7,028	6,143	2,652	2,803	3,289	1,876	1,446	1,666
		4	286	163	263	1,831	5,445	6,120	6,084	7,268	7,677	7,755

			PERIOD									
SOMU	Alt	Frg Cls	1	2	3	4	5	6	7	8	9	10
PLEASANT VALLEY DISP	A	0	764	419	397	175	74	180	183	98	288	372
		1	88	345	324	75	102	65	7	103	103	125
		2	80	111	79	561	245	33		10		10
		3	408	446	410	215	475	675	890	587	243	91
		4	20	38	149	332	464	407	279	562	726	761
	B	0	764	448	403	141	305	374	213	347	261	181
		1	88	316	326	82	81	4	114	144	212	258
		2	80	95	89	555	64	11	62	101	96	133
		3	408	462	502	540	431	631	587	208	152	109
		4	20	38	41	41	478	339	384	559	639	679
	C	0	764	448	441	442	585	584	336	365	251	425
		1	88	316	324	10	37	44	169	297	496	269
		2	80	95	112	546	156	88	211	191	96	153
		3	408	462	442	319	439	445	357	181	148	220
		4	20	38	41	41	142	198	286	326	368	293

			PERIOD									
SOMU	Alt	Frg Cls	1	2	3	4	5	6	7	8	9	10
PLEASANT VALLEY NRF	A	0	706	557	383	306	193	193	110	222	358	300
		1		160	334	107	191	142	151	251	30	61
		2	421	76	16	331	256	79	127	1	106	121
		3	463	613	599	650	383	594	469	392	316	229
		4	154	338	412	350	720	735	886	878	933	1,032
	B	0	706	570	406	319	332	265	257	186	173	166
		1		160	334	44	173	175	105	184	202	157
		2	421	69	56	436	163	53	87	117	109	183
		3	463	644	571	495	304	446	415	474	411	342
		4	154	301	375	449	772	806	879	783	849	896
	C	0	706	557	393	280	384	417	377	185	120	174
		1		160	334	121	149	90	165	207	248	176
		2	421	75	79	355	161	81	8	158	224	247
		3	463	651	562	539	296	337	345	444	342	366
		4	154	301	375	449	754	819	849	749	810	781

			PERIOD									
SOMU	**Alt**	**Frg Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
REESE CREEK	A	0	1,621	1,616	1,510	1,293	342	524	228	319	465	771
		1	335	79	168	214	713	187	42	337	40	45
		2	538	601	417	336	909	645	604	44	70	108
		3	1,697	2,100	1,760	1,646	944	1,937	2,156	1,816	1,152	495
		4	421	216	757	1,122	1,704	1,319	1,581	2,095	2,886	3,192
	B	0	1,621	1,616	1,528	1,117	395	397	705	536	501	613
		1	335	79	164	403	911	521	162	202	8	22
		2	538	563	300	252	240	399	101	164	388	483
		3	1,697	1,831	1,451	1,458	759	678	847	898	781	591
		4	421	523	1,169	1,382	2,307	2,616	2,797	2,813	2,935	2,903
	C	0	1,621	1,656	1,554	1,323	410	922	1,022	678	545	386
		1	335	69	168	217	713	308	213	227	34	287
		2	538	737	528	190	575	191	53	410	695	573
		3	1,697	1,974	2,026	2,009	855	934	808	544	831	838
		4	421	175	336	873	2,059	2,256	2,517	2,752	2,507	2,527

Table G2-3. Acres by Roosting Score Category for Each SOMU Over 10 Decades

			PERIOD									
SOMU	Alt	Rst Cat	1	2	3	4	5	6	7	8	9	10
ASHFORD	A	0	3,596	3,575	3,401	2,655	801	913	470	970	1,307	1,760
		1	126	20	202	684	1,186	341	156	185	175	73
		2	238	255	287	563	1,213	674	972	686	105	374
		3	407	264	409	424	1,135	1,845	2,330	907	1,386	1,183
		4	2,631	2,820	2,479	2,560	2,161	2,965	3,082	4,225	4,193	3,698
		5	567	632	788	680	1,070	827	557	593	401	478
	B	0	3,596	3,609	3,208	2,170	1,587	1,322	1,181	1,312	1,287	1,237
		1	126	20	383	1,332	1,176	290	301	420	402	986
		2	238	240	271	298	591	1,085	566	961	1,024	420
		3	407	224	215	278	694	1,073	1,473	564	398	735
		4	2,631	2,733	2,537	2,541	1,963	2,249	2,577	2,687	3,147	2,624
		5	567	740	953	947	1,556	1,547	1,468	1,622	1,308	1,565
	C	0	3,596	3,629	3,471	2,782	1,312	2,172	2,087	1,154	1,340	1,280
		1	126	20	225	687	1,169	352	371	546	313	645
		2	238	186	238	424	1,179	549	330	592	1,381	1,170
		3	407	223	269	247	474	656	1,042	927	423	730
		4	2,631	2,777	2,399	2,373	1,856	2,413	2,280	2,810	2,641	2,561
		5	567	731	964	1,054	1,576	1,423	1,457	1,537	1,469	1,181

			PERIOD									
SOMU	Alt	Rst Cat	1	2	3	4	5	6	7	8	9	10
BIG CATT	A	0	3,147	2,774	1,652	1,374	387	379	198	747	1,082	1,464
		1	1,177	423	619	636	1,026	168	377	306	203	107
		2	764	1,364	893	406	737	504	262	235	132	174
		3	394	760	1,807	1,679	979	1,774	1,860	1,107	1,098	971
		4	1,440	1,284	1,827	2,650	3,782	3,866	3,479	3,279	3,957	3,532
		5	161	477	284	338	171	392	906	1,410	609	834
	B	0	3,147	2,813	1,550	1,269	649	668	811	910	730	580
		1	1,177	415	662	500	842	146	65	167	393	113
		2	764	1,360	698	355	731	350	320	152	303	641
		3	394	663	1,764	1,367	835	1,052	742	416	386	360
		4	1,440	1,416	1,964	3,120	3,739	3,630	2,777	2,830	3,169	2,830
		5	161	415	445	472	286	1,236	2,367	2,607	2,100	2,560
	C	0	3,147	2,662	1,641	1,820	1,170	1,292	1,268	957	519	723
		1	1,177	386	337	458	933	388	257	616	531	324
		2	764	1,567	732	301	713	208	357	326	999	836
		3	394	736	2,178	1,435	683	1,019	650	431	313	431
		4	1,440	1,657	2,107	2,938	3,403	3,576	3,308	2,448	3,126	3,154
		5	161	74	88	130	180	599	1,242	2,304	1,594	1,614

			PERIOD									
SOMU	**Alt**	**Rst Cat**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
BUSY WILD	A	0	5,830	5,944	5,176	4,854	1,490	3,662	1,301	1,597	3,074	3,546
		1	435	223	715	655	3,000	549	518	542	272	354
		2	715	649	1,067	1,110	1,748	872	2,772	2,721	693	957
		3	959	905	913	1,472	1,980	3,351	3,853	2,608	2,871	2,097
		4	4,782	5,040	5,059	4,843	4,552	4,919	5,183	5,627	6,467	6,012
		5	1,721	1,680	1,512	1,506	1,671	1,089	813	1,347	1,065	1,476
	B	0	5,830	5,913	4,850	4,399	1,824	1,731	3,602	3,075	3,249	3,383
		1	435	247	969	1,207	3,132	650	861	1,516	412	924
		2	715	611	1,047	885	1,394	2,951	713	594	1,164	443
		3	959	722	353	788	627	1,282	1,316	938	1,007	1,246
		4	4,782	4,924	5,144	5,125	4,796	5,612	5,172	5,488	5,737	4,745
		5	1,721	2,024	2,078	2,038	2,668	2,216	2,778	2,830	2,873	3,700
	C	0	5,830	5,958	4,913	5,181	1,902	3,953	4,114	3,200	3,590	3,494
		1	435	280	974	725	3,094	733	893	1,832	597	988
		2	715	407	897	733	1,433	812	495	355	785	663
		3	959	966	604	794	639	1,142	1,169	728	881	1,294
		4	4,782	4,981	5,066	4,993	4,909	5,927	5,446	5,834	6,048	4,916
		5	1,721	1,849	1,987	2,015	2,465	1,874	2,324	2,492	2,540	3,086

			PERIOD									
SOMU	**Alt**	**Rst Cat**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
GRASS MOUNTAIN	A	0	9,236	8,630	7,225	5,524	3,608	2,459	1,684	2,092	3,161	3,249
		1	1,321	457	1,535	2,452	1,342	1,457	1,139	774	574	685
		2	1,441	1,577	695	622	1,997	1,855	1,099	1,144	554	735
		3	959	920	1,725	1,682	2,588	2,934	4,013	3,430	1,997	1,808
		4	3,244	3,919	4,117	5,239	5,789	6,516	6,616	7,384	8,475	8,409
		5	1,267	1,964	2,170	1,946	2,142	2,246	2,916	2,643	2,705	2,579
	B	0	9,236	8,634	7,071	5,555	4,752	3,043	2,820	2,208	1,839	2,277
		1	1,321	470	1,196	2,356	1,310	828	851	1,725	2,420	618
		2	1,441	1,607	1,110	825	1,603	2,028	1,409	398	269	2,034
		3	959	845	1,516	1,289	1,649	1,905	1,579	1,217	694	765
		4	3,244	3,905	4,431	5,295	5,928	6,701	6,548	8,089	8,109	7,500
		5	1,267	2,005	2,141	2,145	2,224	2,961	4,259	3,829	4,136	4,273
	C	0	9,236	8,654	7,313	5,513	3,888	3,014	3,371	3,238	3,136	3,025
		1	1,321	383	1,524	2,672	1,485	1,715	1,208	1,123	1,677	991
		2	1,441	1,610	749	521	2,069	1,478	588	630	770	1,336
		3	959	916	1,552	1,556	1,782	1,930	2,170	1,279	866	1,065
		4	3,244	4,093	4,492	5,490	6,489	7,090	6,949	7,822	7,627	7,770
		5	1,267	1,811	1,837	1,714	1,753	2,239	3,180	3,375	3,391	3,279

			PERIOD									
SOMU	**Alt**	**Rst Cat**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MINERAL CREEK	A	0	2,853	2,776	2,162	1,239	268	17	17	65	576	1,133
		1	238	11	558	923	943	170	0	11	33	29
		2	134	180	177	193	169	956	190	94	54	75
		3	142	320	228	666	1,667	1,284	1,315	559	312	240
		4	777	999	1,152	1,265	1,271	1,775	2,431	2,968	2,836	2,391
		5	239	97	107	96	64	181	429	685	572	515
	B	0	2,853	2,776	2,140	1,218	752	505	66	151	716	718
		1	238	11	558	926	973	205	488	498	519	32
		2	134	174	193	234	99	114	109	34		505
		3	142	247	155	532	1,071	1,388	959	32	62	28
		4	777	925	1,165	1,324	1,257	1,906	1,809	2,464	2,033	2,084
		5	239	251	173	149	231	265	952	1,203	1,052	1,016
	C	0	2,853	2,825	2,226	1,691	1,167	1,081	714	255	399	549
		1	238	11	424	912	952	510	688	1,263	899	452
		2	134	137	130	70	129	68	114	92	434	695
		3	142	283	309	284	683	957	534	18	56	79
		4	777	1,003	1,169	1,302	1,291	1,511	1,863	1,855	1,810	1,879
		5	239	124	124	124	161	257	469	900	785	730

SOMU	Alt	Rst Cat	1	2	3	4	5	6	7	8	9	10
			PERIOD									
NORTH FORK GREEN	A	0	3,065	2,990	3,054	3,084	833	511	349	448	1,168	1,828
		1	922	205	52	358	2,181	668	601	471	125	32
		2	1,240	493	145	14	326	416	178	214	140	386
		3	394	1,872	1,464	885	907	2,490	2,671	729	768	963
		4	1,440	1,510	2,378	2,782	2,825	2,970	2,713	4,524	4,250	3,345
		5	369	360	336	307	359	376	919	1,043	979	878
	B	0	3,065	2,947	2,865	2,665	810	518	399	483	1,785	1,495
		1	922	205	47	444	2,018	410	500	420	231	238
		2	1,240	697	140	14	312	394	113	172	118	449
		3	394	1,661	1,231	795	544	1,938	2,076	261	430	443
		4	1,440	1,460	2,774	3,184	3,206	3,488	2,713	4,431	2,958	2,959
		5	369	460	373	328	541	683	1,629	1,664	1,908	1,847
	C	0	3,065	2,935	3,069	3,049	981	2,018	1,859	460	670	740
		1	922	234	69	376	2,213	502	653	1,753	1,422	1,260
		2	1,240	473	140	8	335	293	49	355	435	515
		3	394	1,859	1,393	850	512	701	831	174	368	425
		4	1,440	1,660	2,485	2,982	2,947	3,214	2,765	3,066	2,960	3,116
		5	369	268	273	165	442	702	1,273	1,621	1,577	1,374

			PERIOD									
SOMU	Alt	Rst Cat	1	2	3	4	5	6	7	8	9	10
NORTH FORK MINERAL	A	0	3,567	2,932	2,214	2,036	1,075	849	315	1,278	1,956	1,940
		1	2,017	501	936	833	1,056	455	772	810	541	219
		2	1,513	2,400	1,010	735	700	789	474	388	209	378
		3	2,064	2,066	3,047	2,802	2,029	2,213	2,826	1,988	1,320	1,533
		4	3,612	4,230	5,021	5,922	7,159	7,531	7,332	6,369	7,814	7,265
		5	104	750	650	549	859	1,041	1,159	2,045	1,039	1,544
	B	0	3,567	2,891	1,713	1,743	1,099	859	967	567	690	827
		1	2,017	501	816	328	952	310	195	709	775	136
		2	1,513	2,298	855	1,101	745	444	353	190	174	875
		3	2,064	1,547	2,761	1,472	1,457	1,336	1,136	651	421	528
		4	3,612	4,892	5,765	7,551	7,333	6,753	5,441	5,361	6,013	5,433
		5	104	750	968	683	1,292	3,175	4,786	5,399	4,804	5,079
	C	0	3,567	2,818	2,255	2,918	2,518	2,062	1,773	1,044	868	1,408
		1	2,017	425	709	595	954	1,050	992	1,760	836	407
		2	1,513	2,270	690	497	507	183	538	703	1,825	1,414
		3	2,064	1,867	3,210	1,889	1,026	916	834	597	402	685
		4	3,612	5,360	5,787	6,900	7,205	7,652	6,816	5,479	5,903	6,214
		5	104	138	228	78	668	1,015	1,924	3,295	3,043	2,750

			PERIOD									
SOMU	**Alt**	**Rst Cat**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PLEASANT VALLEY DISP	A	0	764	419	397	175	74	180	183	98	288	372
		1	88	316	269	75	102	65	7	103	103	125
		2		116	29	347	178	33		7		10
		3	72	23	89	196	13	222	133	79	47	18
		4	367	465	555	397	732	666	910	882	688	618
		5	68	20	20	169	261	193	126	191	234	216
	B	0	764	448	403	141	305	374	213	347	261	181
		1	88	316	271	82	37	1	113	115	196	69
		2		87		220	49	10	36	76	112	236
		3	72	8	118	330	20	228	67	136	32	86
		4	367	480	548	563	908	633	588	376	446	488
		5	68	20	20	22	41	113	342	309	313	300
	C	0	764	448	441	442	585	584	336	365	251	425
		1	88	316	269	10	37	40	169	174	407	137
		2		88		222	75	31	211	239	184	198
		3	72	8	118	319	41	224	41	112	32	86
		4	367	480	511	343	581	439	400	301	371	408
		5	68	20	20	22	41	41	202	169	114	105

			PERIOD									
SOMU	Alt	Rst Cat	1	2	3	4	5	6	7	8	9	10
PLEASANT VALLEY NRF	A	0	706	557	383	306	193	193	110	222	358	300
		1		160	334	106	191	122	160	177	59	91
		2	300	58	9	262	91	80	74	83	86	93
		3	118	351	177	138	70	166	116	50	72	164
		4	476	546	697	758	1,058	1,057	1,121	1,004	738	718
		5	143	72	144	173	142	126	162	208	429	378
	B	0	706	570	406	319	332	265	257	186	173	166
		1		160	334	44	173	127	111	179	127	100
		2	300	60	9	243	19	97	110	150	223	215
		3	118	319	189	233	97	168	74	19	11	184
		4	476	560	643	745	823	787	869	856	638	636
		5	143	73	163	160	299	299	322	352	572	443
	C	0	706	557	393	280	384	417	377	185	120	174
		1		160	334	120	149	78	146	200	186	125
		2	300	60	9	256	21	51	56	146	302	301
		3	118	335	200	166	99	104	36	56	13	104
		4	476	557	648	759	793	793	815	817	571	625
		5	143	73	160	162	297	300	314	339	551	415

			PERIOD									
SOMU	Alt	Rst Cat	1	2	3	4	5	6	7	8	9	10
REESE CREEK	A	0	1,621	1,616	1,510	1,293	342	524	228	319	465	771
		1	335	22	168	303	713	250	107	56	112	77
		2	375	300	156	168	553	519	591	464	65	162
		3	499	463	270	211	523	991	1,521	770	722	371
		4	1,283	2,019	2,373	2,501	2,284	2,195	1,965	2,401	2,935	2,807
		5	499	192	136	136	198	132	200	602	313	423
	B	0	1,621	1,616	1,528	1,117	395	397	705	536	501	613
		1	335	22	164	493	717	227	162	202	8	10
		2	375	326	166	165	518	415	106	149	377	302
		3	499	437	255	177	304	686	773	377	236	342
		4	1,283	1,711	2,209	2,450	2,233	2,762	2,077	2,235	2,364	1,863
		5	499	500	291	210	445	124	789	1,114	1,126	1,481
	C	0	1,621	1,656	1,554	1,323	410	922	1,022	678	545	386
		1	335	22	177	308	722	251	213	213	27	96
		2	375	278	169	140	533	152	91	118	636	722
		3	499	456	273	254	253	446	433	447	153	180
		4	1,283	2,054	2,341	2,490	2,310	2,617	2,066	1,908	1,710	2,217
		5	499	146	97	97	384	224	786	1,247	1,540	1,010

Table G2-3. Acres by Movement Habitat Class (Mov Cls) for Each SOMU Over 10 Decades

			PERIOD									
SOMU	Alt	Mov Cls	1	2	3	4	5	6	7	8	9	10
ASHFORD	A	0	3,596	3,575	3,363	2,655	706	913	470	970	1,231	1,721
		1	91	20	247	684	1,345	492	311	702	222	170
		2	114	173	178	399	1,351	672	758	176	103	610
		3	607	438	611	829	1,476	2,906	3,012	1,521	1,725	1,214
		4	979	1,074	929	937	871	1,369	2,065	3,053	2,409	2,451
		5	2,179	2,287	2,239	2,061	1,817	1,214	951	1,143	1,875	1,399
	B	0	3,596	3,609	3,169	2,170	1,587	1,277	1,181	1,110	1,287	1,004
		1	91	20	428	1,332	1,349	1,093	386	891	1,206	1,583
		2	114	135	133	195	309	508	922	718	211	385
		3	607	269	286	497	901	1,037	1,049	427	254	369
		4	979	1,015	1,078	1,053	959	1,020	1,487	1,367	1,044	623
		5	2,179	2,517	2,472	2,319	2,461	2,631	2,541	3,054	3,565	3,603
	C	0	3,596	3,629	3,433	2,760	1,275	2,165	1,865	925	1,228	1,268
		1	91	20	270	708	1,294	588	674	1,070	1,081	1,676
		2	114	94	129	357	1,056	376	380	959	903	447
		3	607	375	291	298	524	865	865	156	151	320
		4	979	974	1,079	871	727	967	1,378	1,525	951	625
		5	2,179	2,474	2,365	2,572	2,691	2,605	2,403	2,931	3,252	3,230

			PERIOD									
SOMU	**Alt**	**Mov Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
BIG CATT	A	0	3,147	2,773	1,652	1,359	242	379	198	733	1,014	999
		1	1,323	860	943	618	1,171	158	187	236	214	621
		2	573	1,187	799	556	800	884	411	318	252	138
		3	766	280	1,093	1,157	1,269	2,027	2,080	1,571	1,234	1,165
		4	800	870	1,660	2,370	2,394	2,351	2,680	2,250	1,961	1,604
		5	473	1,112	934	1,022	1,206	1,284	1,527	1,974	2,408	2,555
	B	0	3,147	2,812	1,550	1,223	649	565	612	732	655	408
		1	1,323	829	1,035	538	905	313	274	352	611	562
		2	573	1,134	799	330	562	413	249	269	76	385
		3	766	372	1,194	1,612	1,024	1,382	702	364	345	303
		4	800	620	1,082	1,932	1,984	1,681	1,582	1,694	1,102	694
		5	473	1,316	1,422	1,447	1,958	2,728	3,664	3,672	4,293	4,731
	C	0	3,147	2,635	1,641	1,673	1,170	894	975	702	399	563
		1	1,323	761	621	527	843	704	584	993	948	903
		2	573	1,183	756	291	697	376	280	321	699	418
		3	766	416	1,700	1,378	873	1,262	666	400	214	404
		4	800	1,555	1,888	2,645	2,460	2,205	2,238	1,322	898	993
		5	473	533	476	568	1,039	1,641	2,339	3,344	3,925	3,801

			PERIOD									
SOMU	**Alt**	**Mov Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
BUSY WILD	A	0	5,763	5,944	5,176	4,739	1,422	3,610	1,301	1,585	3,064	3,543
		1	473	156	809	725	3,073	514	408	2,697	236	492
		2	338	582	727	987	1,375	670	2,547	503	726	689
		3	1,201	782	1,276	2,545	3,680	5,258	5,107	3,480	3,250	2,606
		4	1,624	2,206	2,457	1,670	1,813	2,359	2,914	3,438	3,658	4,047
		5	5,043	4,772	3,996	3,776	3,078	2,031	2,163	2,739	3,508	3,065
	B	0	5,763	5,912	4,850	4,300	1,817	1,713	3,601	3,066	3,249	3,346
		1	473	202	1,072	1,252	3,483	3,026	833	1,464	820	920
		2	338	488	659	731	666	497	509	484	632	445
		3	1,201	557	482	1,328	1,384	1,603	1,546	1,027	921	1,404
		4	1,624	1,631	2,227	1,772	2,702	2,484	1,851	1,564	1,378	916
		5	5,043	5,651	5,152	5,059	4,390	5,118	6,101	6,837	7,441	7,410
	C	0	5,763	5,958	4,913	5,064	1,889	3,825	4,087	3,179	3,575	3,489
		1	473	248	1,014	819	3,086	1,200	851	1,678	634	1,075
		2	338	246	479	546	1,217	352	388	566	918	672
		3	1,201	585	584	879	1,122	1,562	1,354	650	673	1,088
		4	1,624	1,919	2,337	1,798	2,634	2,407	2,372	1,980	1,668	1,255
		5	5,043	5,485	5,114	5,335	4,494	5,096	5,388	6,388	6,973	6,862

			PERIOD									
SOMU	Alt	Mov Cls	1	2	3	4	5	6	7	8	9	10
GRASS MOUNTAIN	A	0	9,236	8,581	7,150	5,524	3,567	2,442	1,678	1,611	3,048	2,680
		1	1,699	1,297	1,953	2,692	1,744	1,664	880	1,164	795	1,511
		2	954	1,088	512	271	1,553	1,803	1,322	1,052	843	394
		3	1,253	470	1,110	2,010	2,822	3,112	4,793	3,824	3,378	3,373
		4	1,534	2,276	2,560	2,126	2,823	3,811	3,567	4,326	3,531	3,736
		5	2,791	3,754	4,180	4,843	4,957	4,634	5,227	5,489	5,871	5,772
	B	0	9,236	8,585	6,996	5,359	4,645	1,893	2,312	2,095	1,564	1,855
		1	1,699	1,267	1,884	2,964	1,507	2,600	1,410	1,926	2,695	1,358
		2	954	1,109	561	265	1,286	995	1,055	311	218	1,727
		3	1,253	457	1,007	1,606	1,965	2,645	2,979	2,561	2,389	2,062
		4	1,534	2,235	2,840	2,156	2,997	3,252	2,633	3,303	2,645	2,548
		5	2,791	3,814	4,178	5,117	5,066	6,081	7,077	7,270	7,956	7,917
	C	0	9,236	8,605	7,237	5,349	3,681	2,726	2,723	2,608	2,077	2,843
		1	1,699	1,143	1,760	3,051	1,595	1,918	1,914	1,855	2,786	1,631
		2	954	1,106	582	176	1,491	1,378	525	553	678	869
		3	1,253	433	1,183	1,890	2,473	2,227	3,371	2,308	2,289	2,338
		4	1,534	2,791	3,531	3,091	3,748	3,776	2,815	3,339	2,585	2,837
		5	2,791	3,388	3,173	3,910	4,478	5,441	6,119	6,803	7,052	6,947

			PERIOD									
SOMU	**Alt**	**Mov Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MINERAL CREEK	A	0	2,853	2,774	2,128	1,239	247	17	17	65	576	1,114
		1	238	152	670	923	965	265	22	11	33	48
		2	199	165	86	546	1,121	848	162	78	44	65
		3	463	164	326	448	901	1,555	1,468	1,393	554	523
		4	108	478	492	491	473	1,006	1,834	1,937	2,147	1,578
		5	521	651	682	735	677	691	879	899	1,029	1,054
	B	0	2,853	2,774	2,106	1,218	752	494	66	151	716	623
		1	238	152	670	941	942	258	456	466	487	572
		2	199	197	117	535	310	102	141	66	32	60
		3	463	72	140	292	879	1,484	960	25	51	31
		4	108	388	621	455	340	720	1,048	1,551	503	492
		5	521	800	729	942	1,160	1,326	1,711	2,123	2,594	2,604
	C	0	2,853	2,824	2,191	1,633	1,146	917	708	255	308	454
		1	238	105	536	969	963	685	705	1,253	1,193	1,076
		2	199	172	47	64	187	50	103	102	232	165
		3	463	116	202	378	634	1,042	548	23	56	94
		4	108	691	980	716	545	647	958	878	231	238
		5	521	475	427	622	907	1,040	1,361	1,872	2,364	2,356

			PERIOD									
SOMU	**Alt**	**Mov Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
NORTH FORK GREEN	A	0	3,065	2,990	3,050	3,056	737	506	349	419	1,168	1,788
		1	1,590	350	189	386	2,284	694	586	589	180	95
		2	402	940	94	14	535	1,774	237	140	123	513
		3	919	985	1,132	959	850	1,408	2,987	1,113	1,008	1,068
		4	721	714	1,473	1,269	1,274	1,213	1,292	2,971	2,683	1,709
		5	734	1,451	1,491	1,745	1,751	1,835	1,978	2,198	2,269	2,259
	B	0	3,065	2,946	2,861	2,665	735	483	386	474	1,785	1,468
		1	1,590	350	184	444	2,181	586	557	485	249	389
		2	402	951	179	14	223	365	50	111	107	333
		3	919	975	869	911	665	1,980	2,216	532	511	476
		4	721	686	1,800	1,512	1,423	1,416	879	2,278	843	726
		5	734	1,522	1,537	1,883	2,203	2,600	3,342	3,550	3,936	4,039
	C	0	3,065	2,934	3,065	3,032	852	1,832	1,851	452	608	731
		1	1,590	379	206	393	2,322	725	674	1,929	1,558	1,473
		2	402	921	179	8	328	250	26	188	360	293
		3	919	978	1,219	1,015	648	973	1,030	449	491	543
		4	721	876	1,700	1,790	1,623	1,503	1,128	1,182	676	623
		5	734	1,342	1,061	1,193	1,656	2,148	2,721	3,231	3,737	3,767

			PERIOD									
SOMU	**Alt**	**Mov Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
NORTH FORK MINERAL	A	0	3,567	2,891	2,212	1,950	616	789	315	1,227	1,831	1,064
		1	2,485	1,547	1,230	920	1,754	830	741	960	644	1,073
		2	1,058	1,609	642	782	413	659	452	253	197	363
		3	2,137	662	1,954	1,926	2,137	2,473	3,082	2,366	2,174	2,130
		4	2,416	3,507	4,333	4,334	5,266	5,584	5,163	4,032	3,088	2,946
		5	1,214	2,660	2,507	2,966	2,692	2,542	3,125	4,040	4,944	5,302
	B	0	3,567	2,850	1,711	1,672	1,088	373	735	533	681	758
		1	2,485	1,532	1,223	559	1,084	1,006	410	736	756	203
		2	1,058	1,656	674	964	584	308	311	131	162	858
		3	2,137	652	2,217	1,828	1,460	1,527	1,031	742	512	488
		4	2,416	3,301	3,683	3,715	4,727	3,778	2,786	2,934	1,340	1,222
		5	1,214	2,888	3,369	4,140	3,935	5,886	7,606	7,802	9,426	9,349
	C	0	3,567	2,769	2,253	2,584	2,288	1,220	1,435	1,028	722	1,140
		1	2,485	1,421	985	929	1,162	1,839	1,332	1,806	1,372	851
		2	1,058	1,320	574	409	512	254	490	674	1,437	1,230
		3	2,137	750	2,072	1,821	1,082	1,176	715	484	508	674
		4	2,416	5,148	5,316	4,784	5,379	4,970	4,209	3,032	1,322	2,242
		5	1,214	1,469	1,678	2,352	2,453	3,420	4,696	5,855	7,517	6,742

			PERIOD									
SOMU	**Alt**	**Mov Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PLEASANT VALLEY DISP	A	0	764	419	397	175	74	180	183	98	278	354
		1	75	316	269	75	204	65	7	103	112	154
		2	13	75		347	75	33		10		
		3	200	85	42	13	222	395	151	232	144	18
		4	222	254	313	181	304	229	768	366	328	388
		5	87	211	338	568	480	458	251	550	497	445
	B	0	764	448	403	141	305	346	200	319	261	181
		1	75	316	271	82	81	33	162	186	267	299
		2	13	74		220	11	11	27	74	40	92
		3	200	85	13	13	220	228	41	82	32	
		4	222	187	358	488	395	291	490	119	157	151
		5	87	248	314	415	347	451	440	580	602	637
	C	0	764	448	441	442	585	461	288	337	251	425
		1	75	316	269	10	37	167	368	435	524	336
		2	13	75		222	103	88	61	74	67	86
		3	200	13	13	13	159	168	41	42	32	
		4	222	268	394	154	144	57	260	113	99	93
		5	87	240	242	517	331	419	343	359	386	420

			PERIOD									
SOMU	Alt	Mov Cls	1	2	3	4	5	6	7	8	9	10
PLEASANT VALLEY NRF	A	0	706	557	383	257	193	166	110	222	323	226
		1	106	160	334	155	273	169	178	252	94	170
		2	203	116	9	194	9	88	56	9	87	96
		3	80	259	190	200	190	167	183	146	139	185
		4	100	235	380	183	501	593	544	287	374	262
		5	549	417	448	755	578	561	672	828	726	804
	B	0	706	570	406	299	322	229	187	148	173	166
		1	106	160	334	65	183	231	211	290	241	157
		2	203	94		115	11	28	52	50	111	214
		3	80	259	175	184	146	140	66	40	1	126
		4	100	214	357	186	263	297	400	192	232	45
		5	549	446	472	895	818	818	828	1,025	986	1,036
	C	0	706	557	393	268	353	409	283	134	105	174
		1	106	160	334	133	192	108	267	346	345	237
		2	203	118		184	0		0	69	141	187
		3	80	241	191	197	136	104	28	29	1	104
		4	100	215	332	94	306	220	332	144	142	34
		5	549	453	493	866	756	902	834	1,021	1,009	1,008

			PERIOD									
SOMU	**Alt**	**Mov Cls**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
REESE CREEK	A	0	1,621	1,616	1,510	1,293	342	524	228	319	465	757
		1	414	239	168	232	713	199	69	324	40	47
		2	217	211	137	259	644	568	535	91	158	119
		3	943	154	415	612	755	1,483	1,778	1,204	1,063	686
		4	338	1,366	1,249	877	1,096	1,425	1,346	1,605	1,452	1,710
		5	1,079	1,025	1,133	1,338	1,063	412	657	1,070	1,435	1,293
	B	0	1,621	1,616	1,528	1,117	376	397	705	536	487	586
		1	414	239	164	422	930	533	162	206	56	156
		2	217	182	137	207	294	386	192	200	313	258
		3	943	208	190	611	502	535	563	241	171	247
		4	338	945	1,242	890	1,274	1,420	737	741	656	419
		5	1,079	1,421	1,352	1,365	1,235	1,340	2,253	2,689	2,928	2,946
	C	0	1,621	1,656	1,554	1,323	391	908	1,022	478	421	359
		1	414	230	177	236	732	374	227	427	393	768
		2	217	110	86	195	487	39	68	451	448	172
		3	943	209	576	665	293	579	354	45	94	53
		4	338	1,744	1,820	1,414	1,821	1,192	855	615	230	490
		5	1,079	664	399	778	888	1,520	2,086	2,597	3,025	2,769

3: Model Results: EMDS-DAT Stand scores of 0.5 and above.

Part 1: Results for all Northern Spotted Owl Dispersal Management Areas Combined

In the South Puget Planning Unit (Elbe Hills, Tahoma, Pleasant Valley, Enumclaw). Scores reported are for “high” to “full” support (EMDS scores 0.5 and greater).

Chart G3-1. Foraging Scores of High Support (EMDS $\geq$ 0.5) Reported in Acres Per Decade Planning Unit.

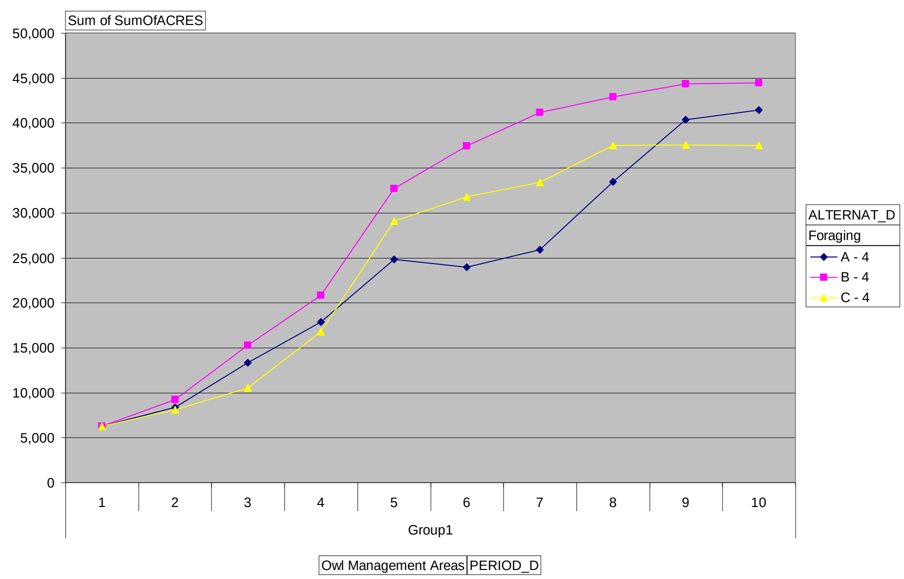


Chart G3-2 Roosting Scores of High Support Reported in Acres Per Decade Planning Unit

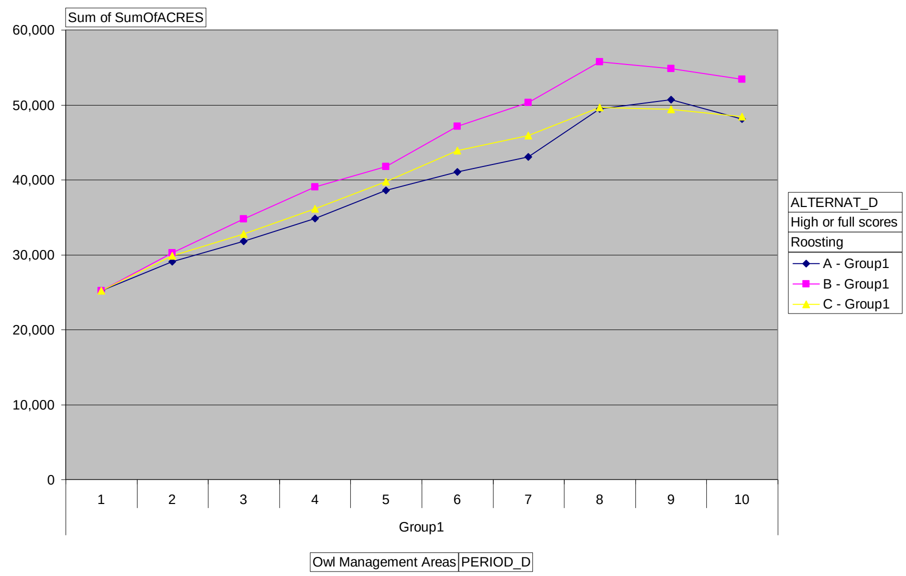
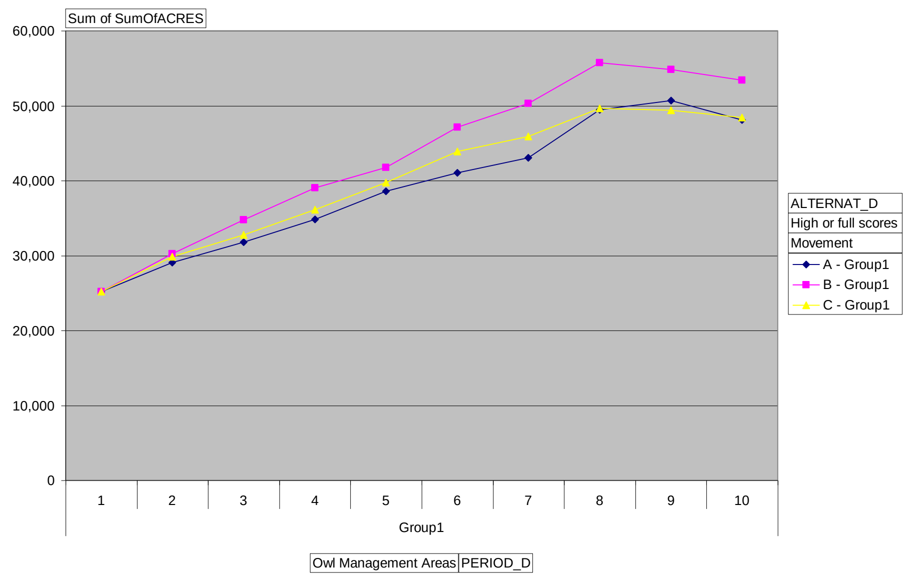


Chart G3-3 Movement Scores of High Support Reported in Acres Per Decade Planning Unit



Part 2: Results for Dispersal Management Areas Only
Elbe Dispersal Management Area

Chart G3-4 Elbe Dispersal Foraging Scores of High Support > 0.5

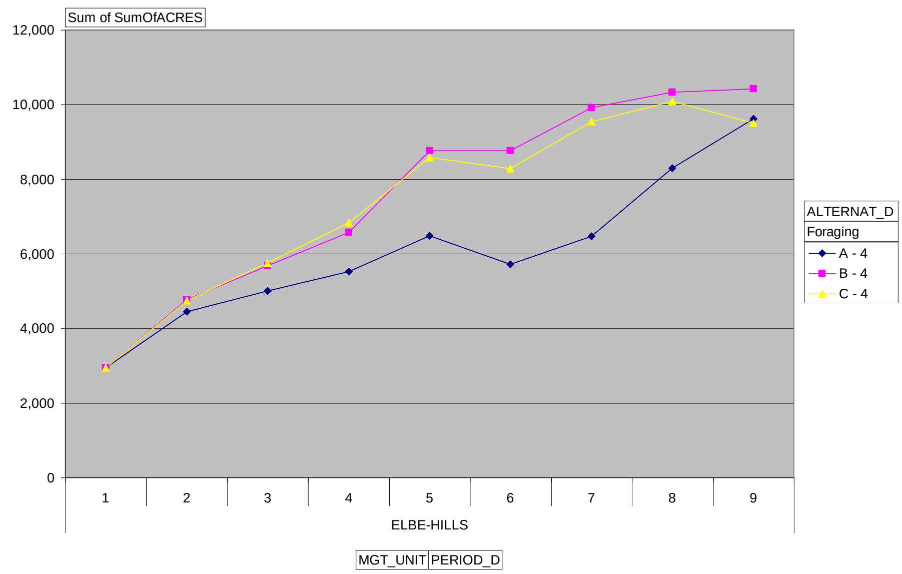


Chart G3-5Elbe Dispersal Roosting Scores of High Support > 0.5

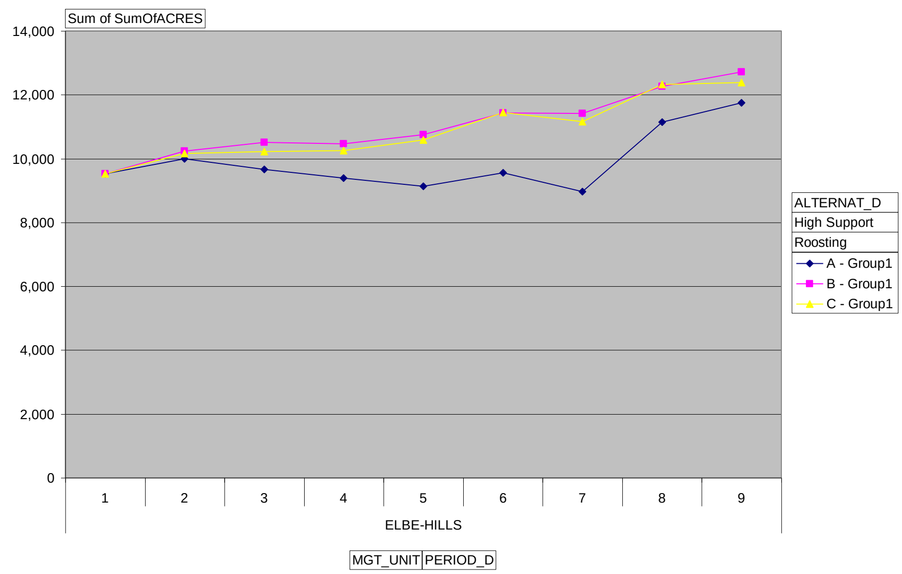
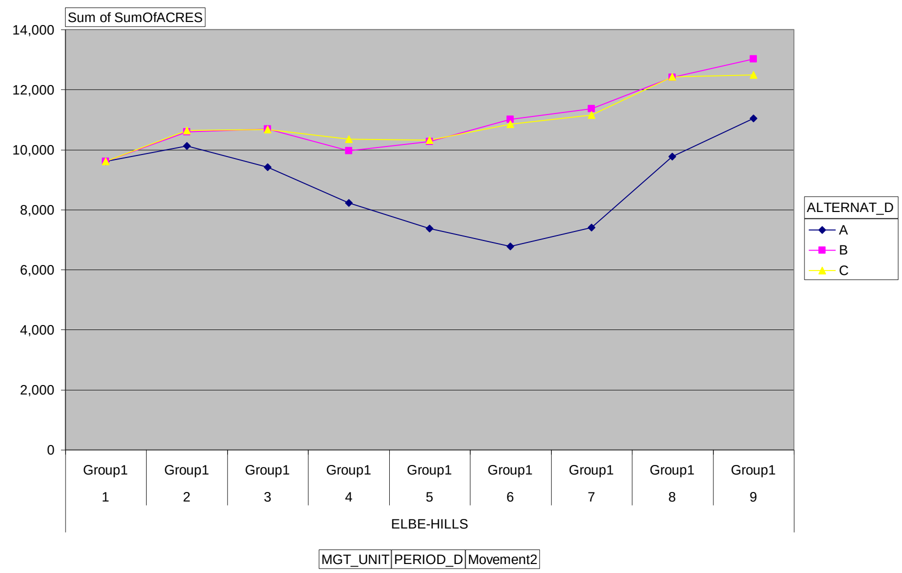


Chart G3-6 Elbe Dispersal Movement Scores of High Support > 0.5



Busy Wild SOMU Dispersal Management Area

Chart G3-7 Busy Wild SOMU Foraging Scores of High Support > 0.5

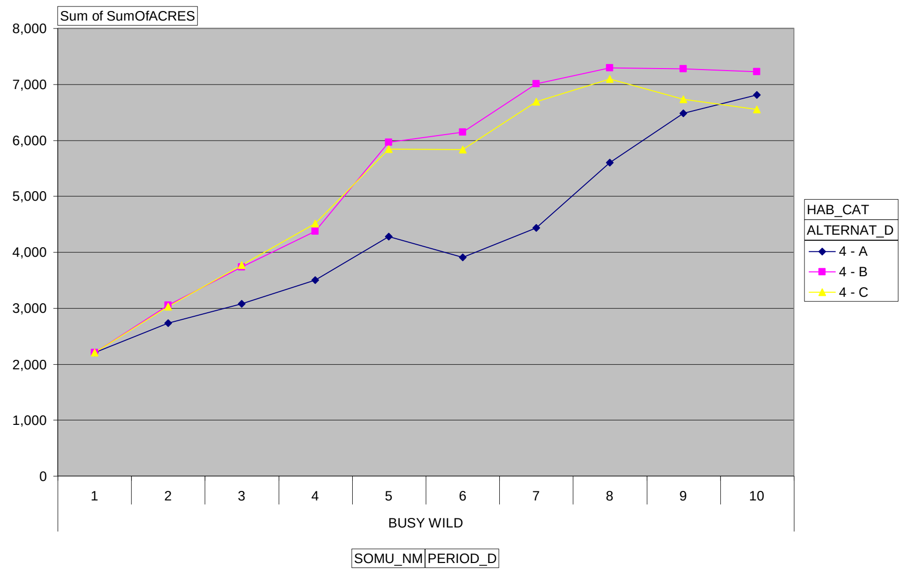


Chart G3-8 Busy Wild SOMU Roosting Scores of High Support > 0.5

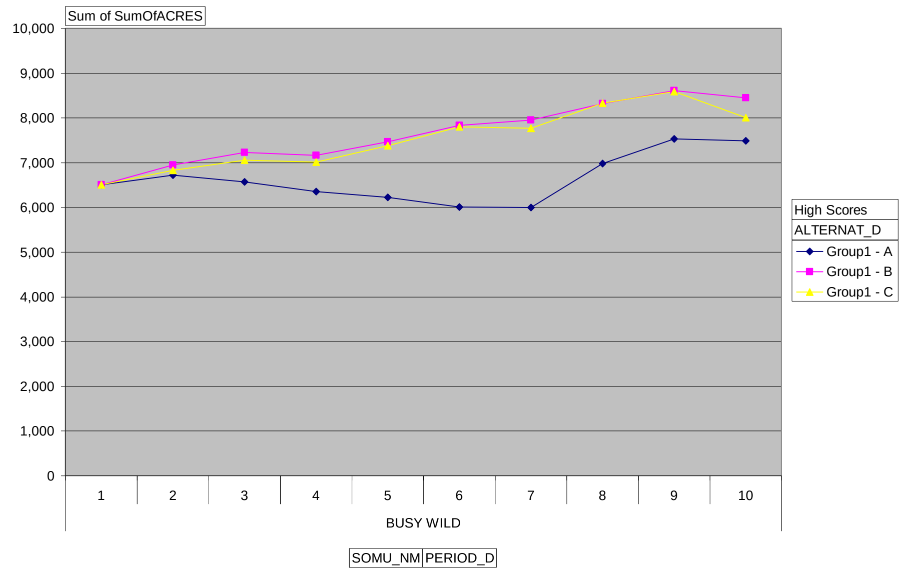
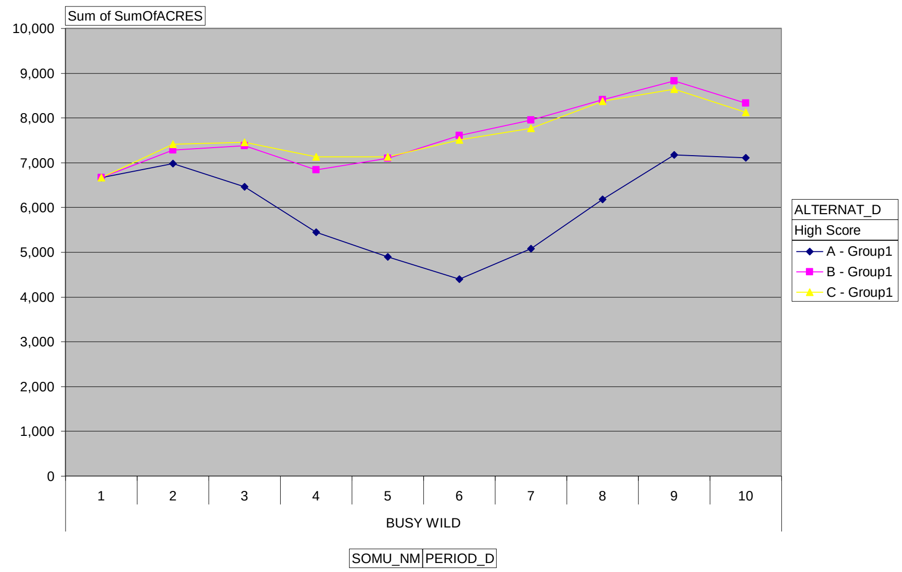


Chart G3-9 Busy Wild SOMU Movement Scores of High Support > 0.5



Ashford SOMU Dispersal Management Area

Chart G3-10 Ashford SOMU Foraging Scores of High Support > 0.5

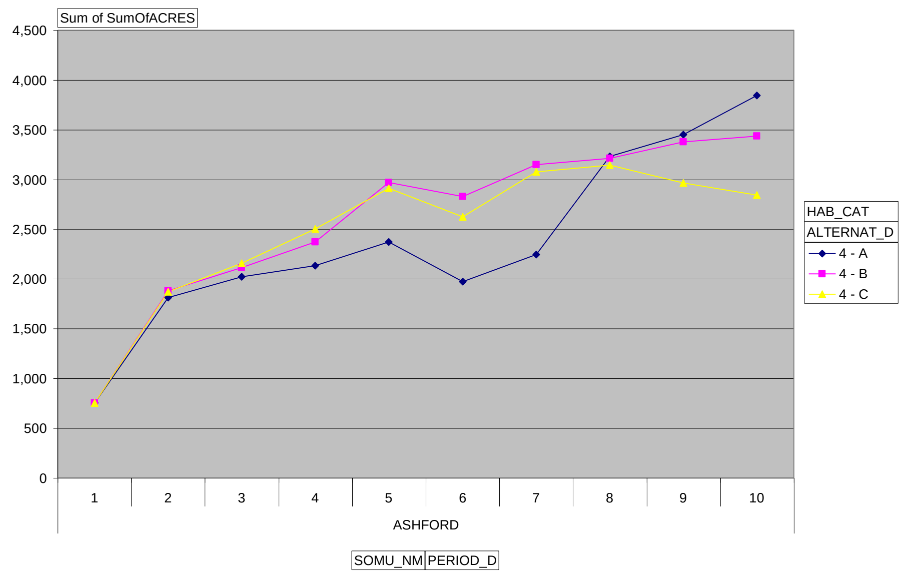


Chart G3-11 Ashford SOMU Roosting Scores of High Support > 0.5

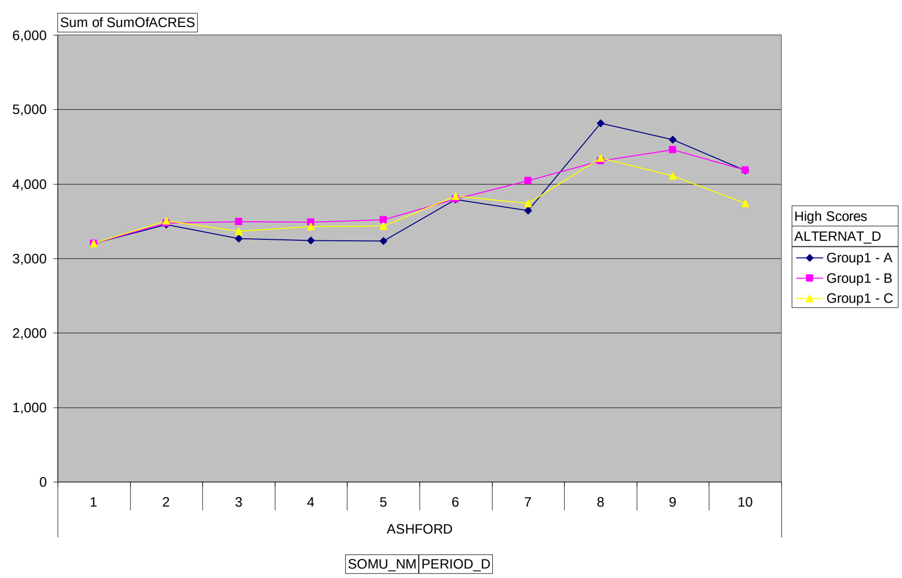
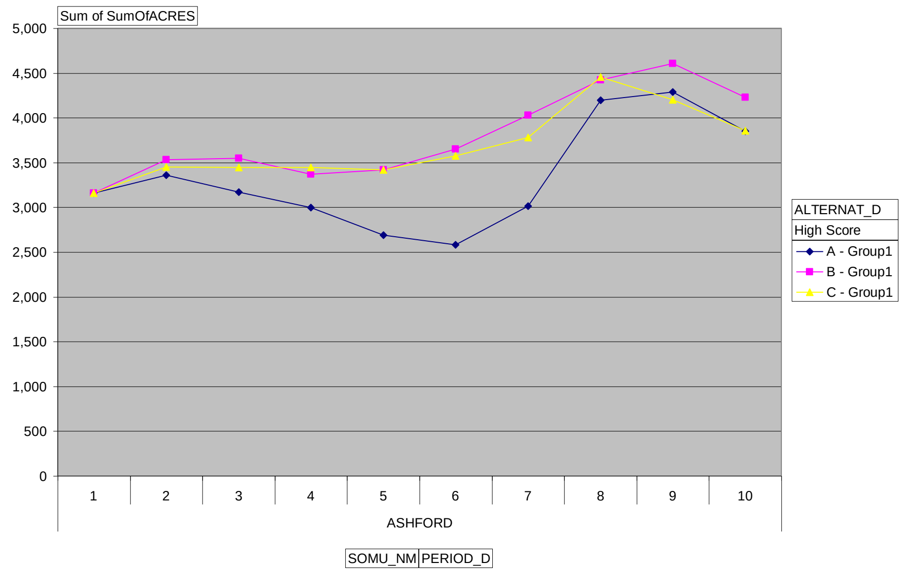


Chart G3-12 Ashford SOMU Movement Scores of High Support > 0.5



Tahoma Dispersal Management Area

Chart G3-13 Tahoma Dispersal Foraging Scores of High Support > 0.5

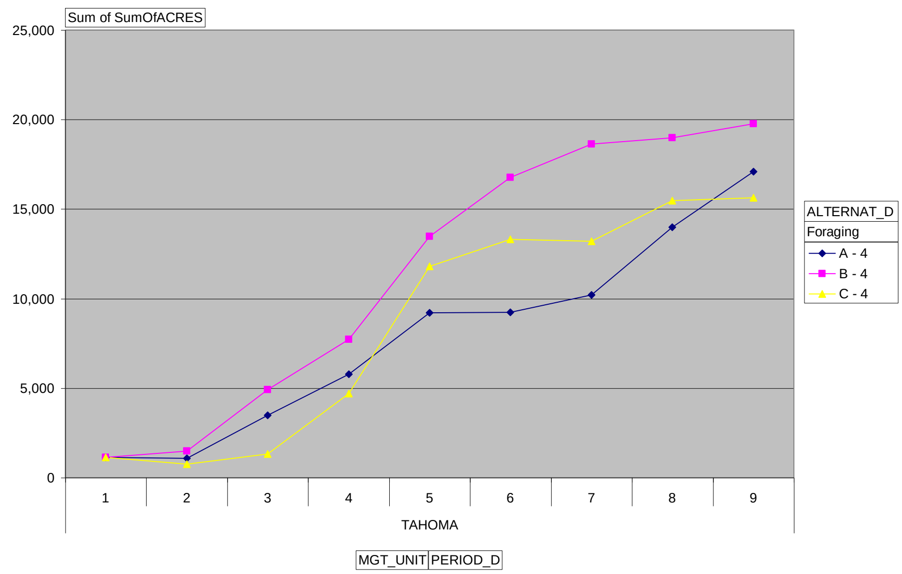


Chart G3-14 Tahoma Dispersal Roosting Scores of High Support > 0.5

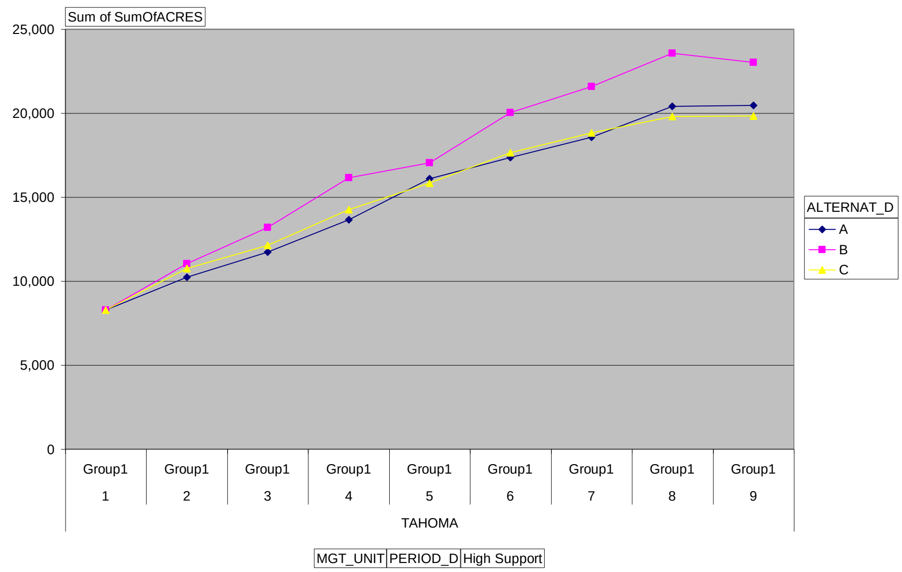
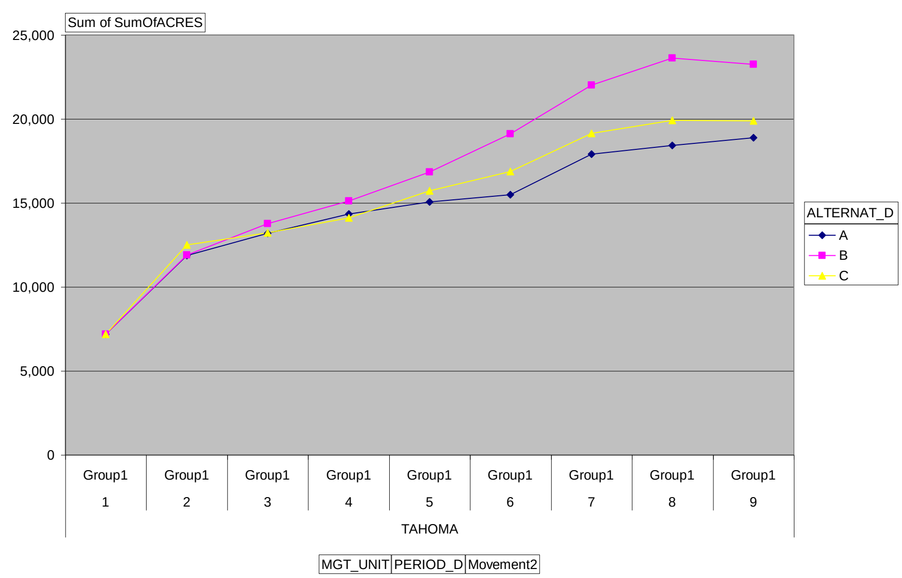


Chart G3-15 Tahoma Dispersal Movement Scores of High Support > 0.5



SOMUs in Tahoma Dispersal Management Area
Big Catt Creek SOMU

Chart G3-16 Big Catt SOMU Foraging Scores of High Support > 0.5

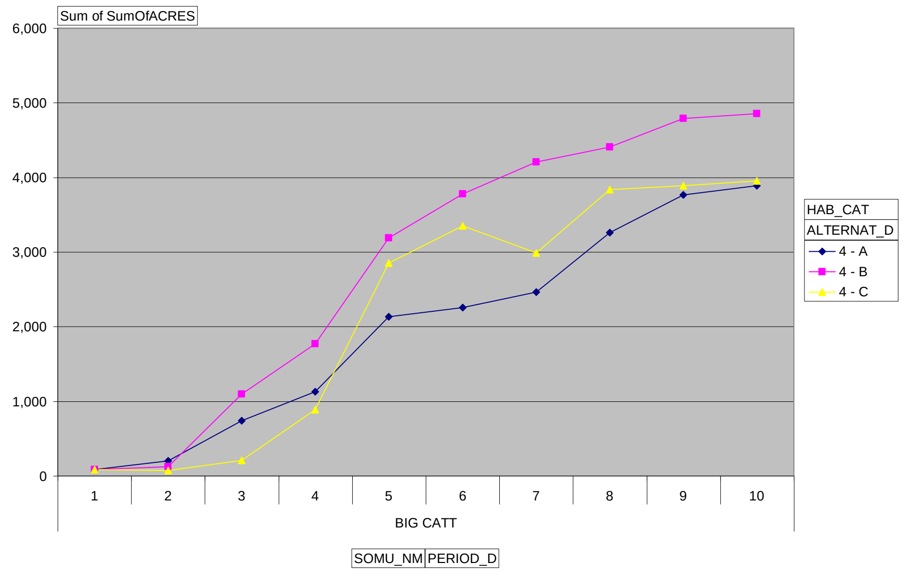


Chart G3-17 Big Catt SOMU Roosting Scores of High Support > 0.5

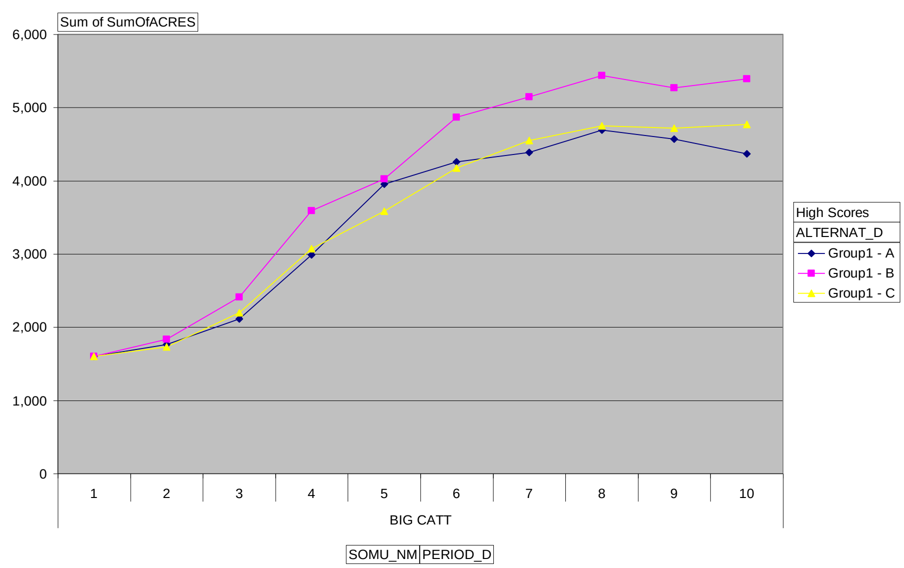
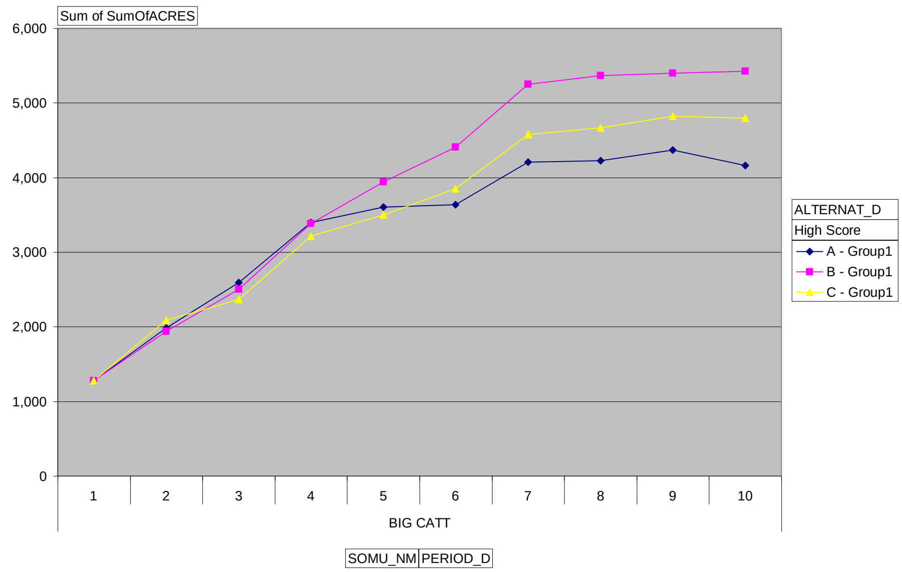


Chart G3-18 Big Catt SOMU Movement Scores of High Support > 0.5



Mineral Creek SOMU

Chart G3-19 Mineral Creek SOMU Foraging Scores of High Support > 0.5

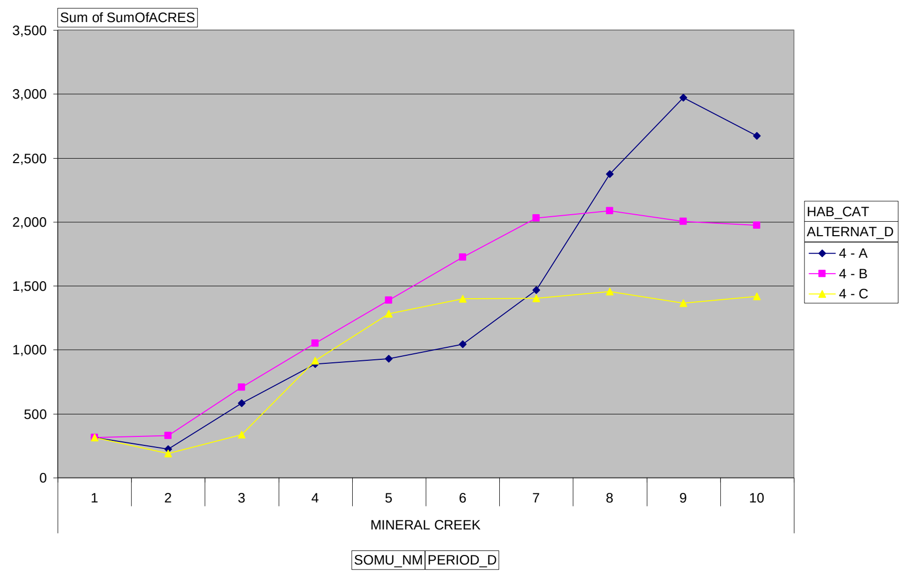


Chart G3-20 Mineral Creek SOMU Roosting Scores of High Support > 0.5

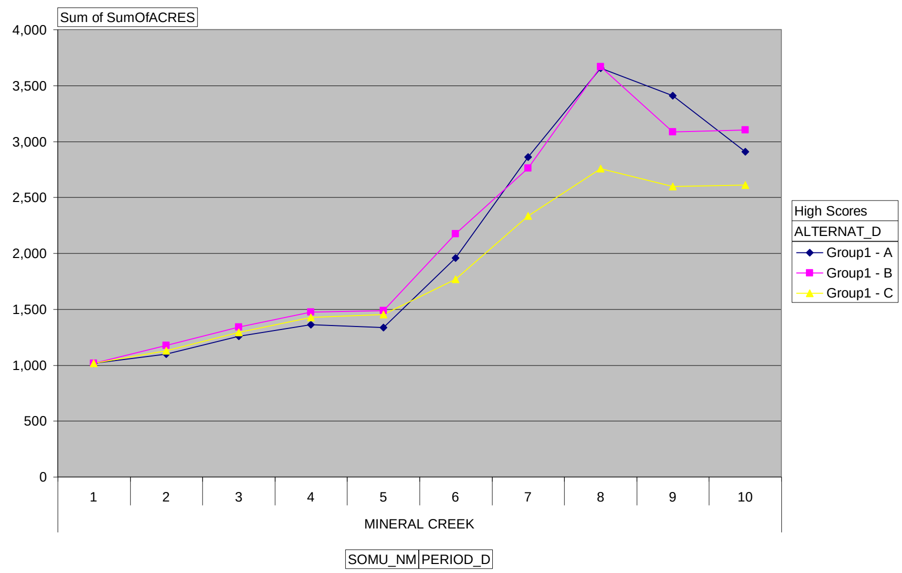
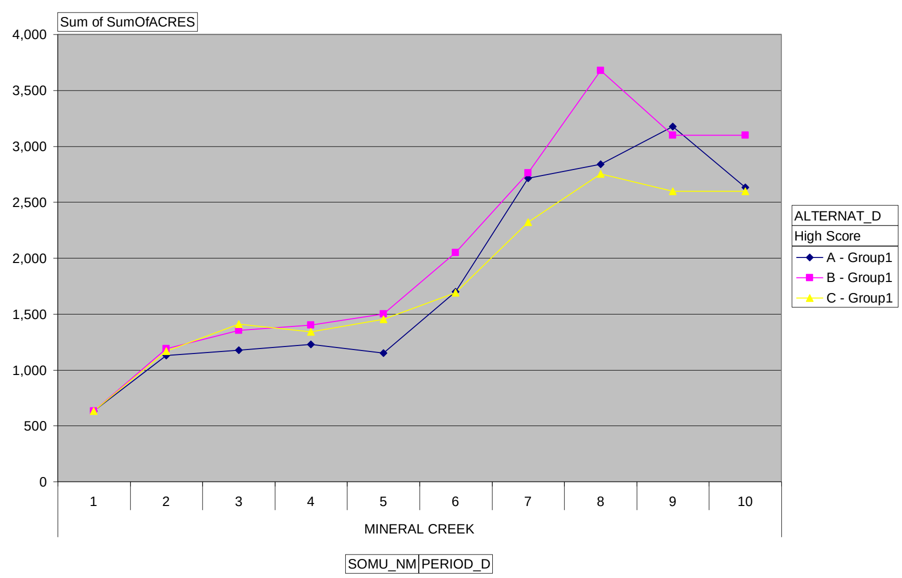


Chart G3-21 Mineral Creek SOMU Movement Scores of High Support > 0.5



North Fork Mineral Creek SOMU

Chart G3-22 North Fork Mineral SOMU Foraging Scores of High Support > 0.5

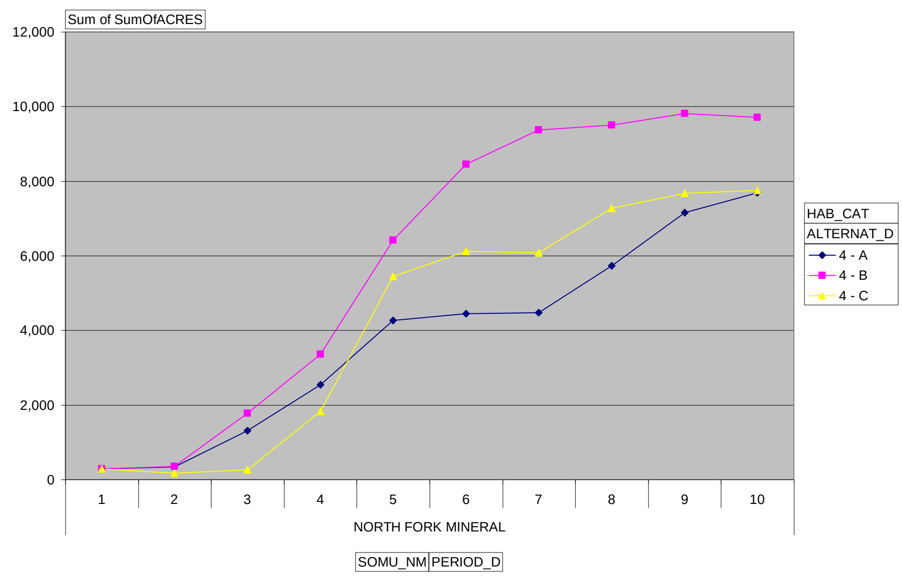


Chart G3-23 North Fork Mineral SOMU Roosting Scores of High Support > 0.5

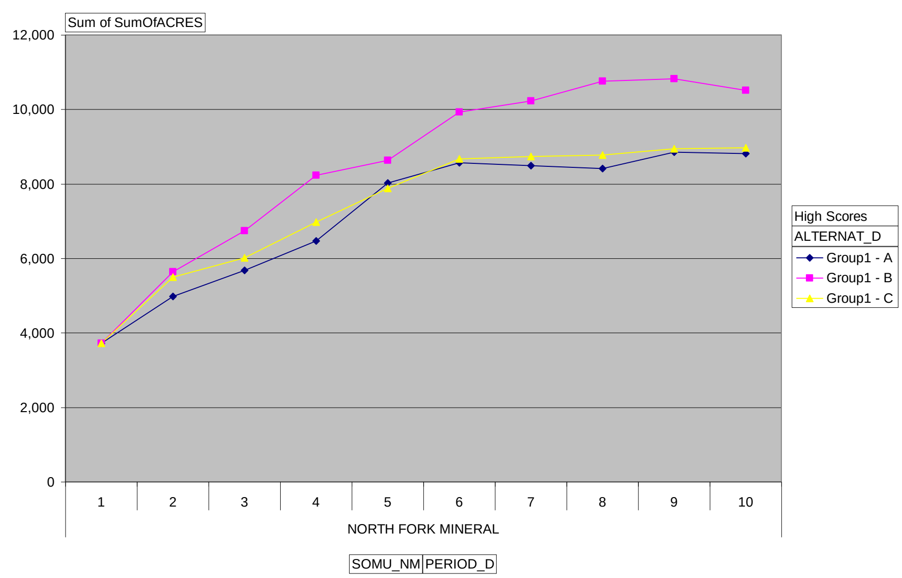
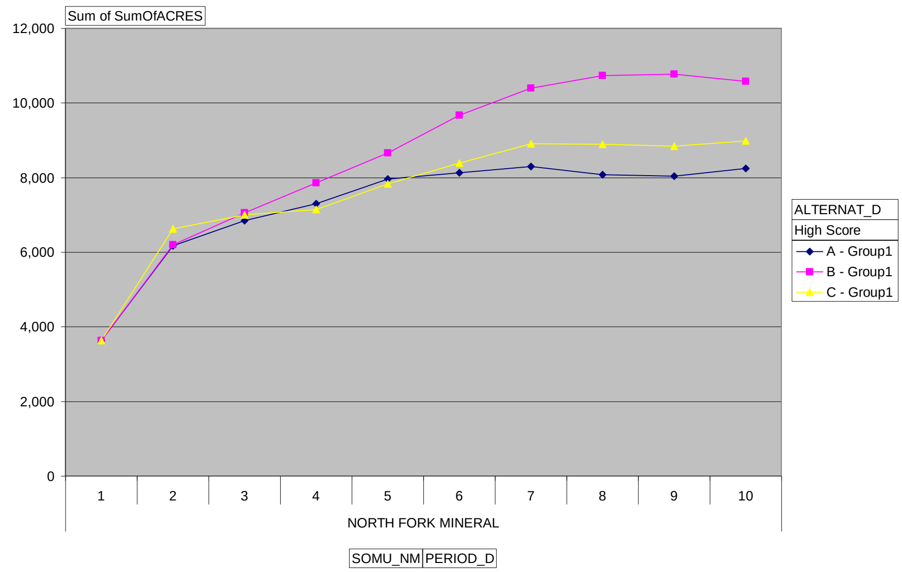


Chart G3-24 North Fork Mineral SOMU Movement Scores of High Support > 0.5



Reese Creek SOMU

Chart G3-25 Reese Creek SOMU Foraging Scores of High Support > 0.5

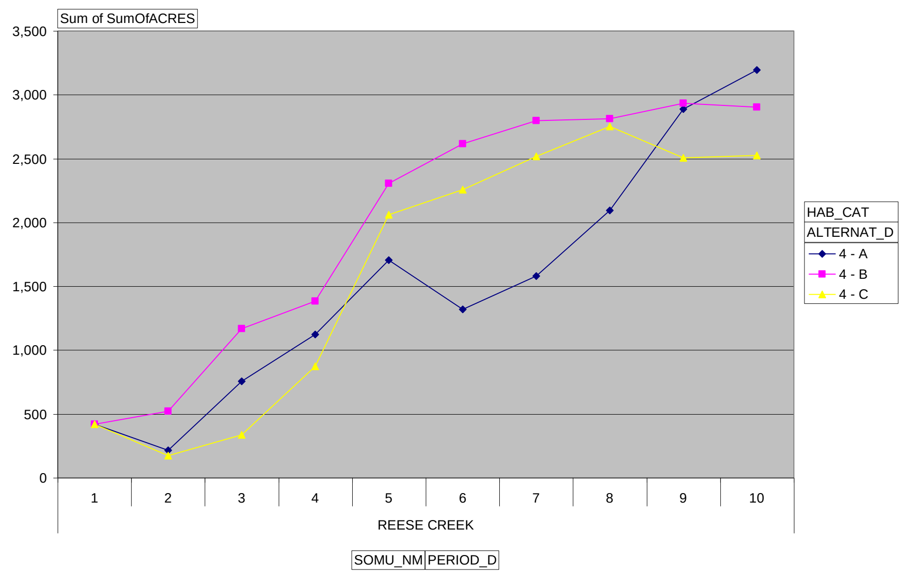


Chart G3-26 Reese Creek SOMU Roosting Scores of High Support > 0.5

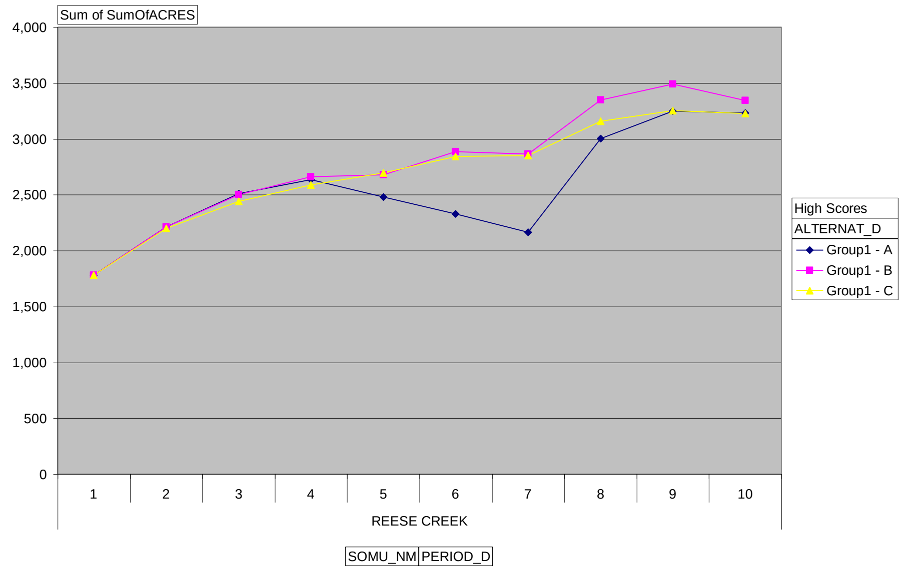
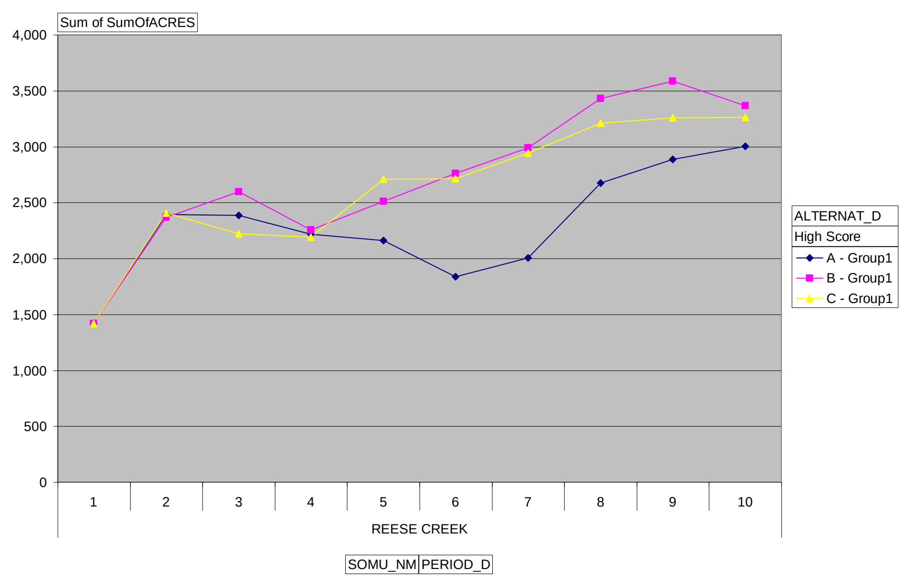


Chart G3-27 Reese Creek SOMU Movement Scores of High Support > 0.5



Pleasant Valley Dispersal Management Area and SOMU

Chart G3-28 Pleasant Valley SOMU Foraging Scores of High Support > 0.5

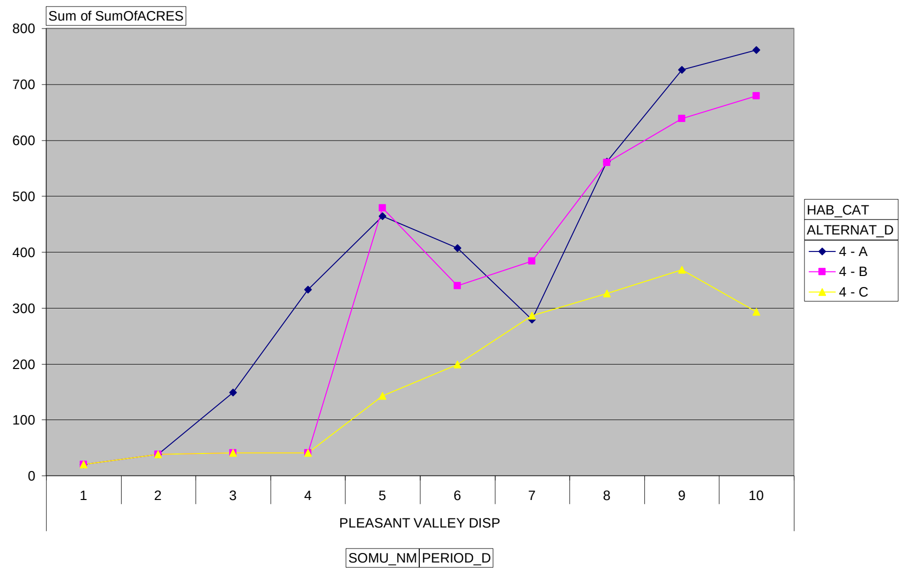


Chart G3-29 Pleasant Valley SOMU Roosting Scores of High Support > 0.5

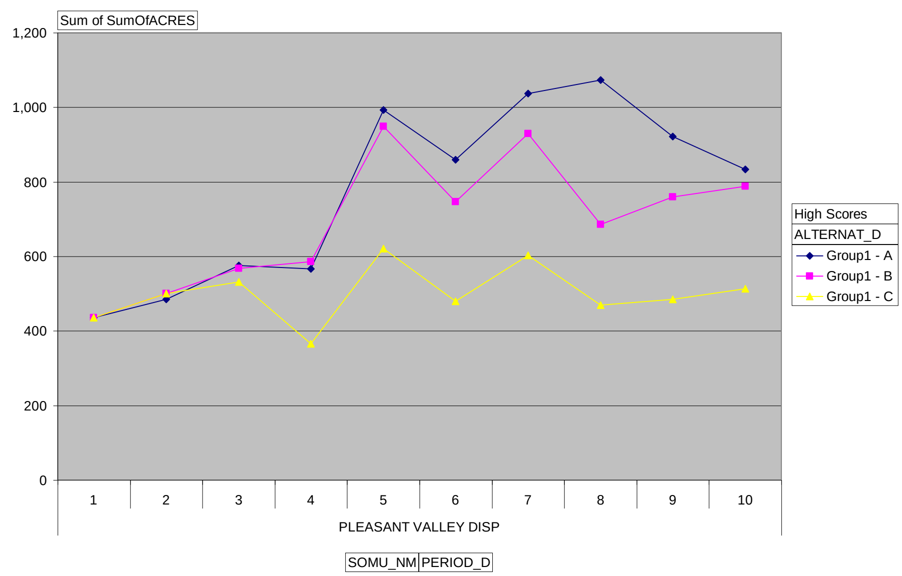
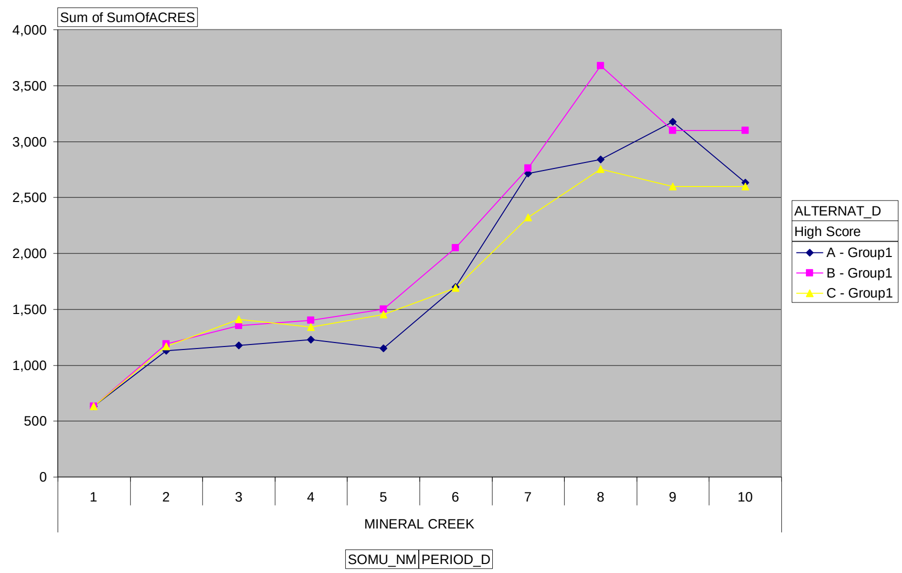


Chart G3-30 Mineral Creek SOMU Movement Scores of High Support > 0.5



Black Diamond Dispersal Management Area

Chart G3-31 Tahoma Dispersal Management Foraging Scores of High Support > 0.5

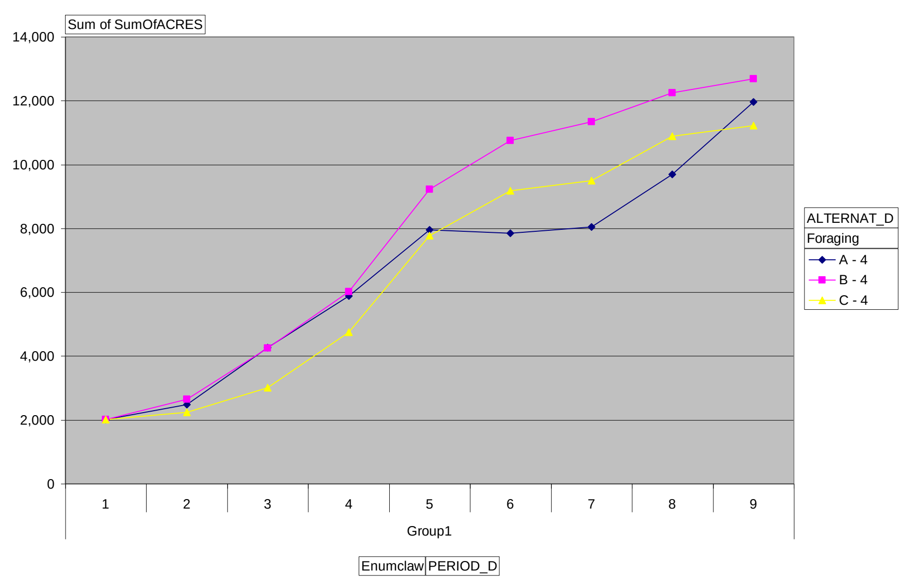


Chart G3-32 Tahoma Dispersal Management Roosting Scores of High Support > 0.5

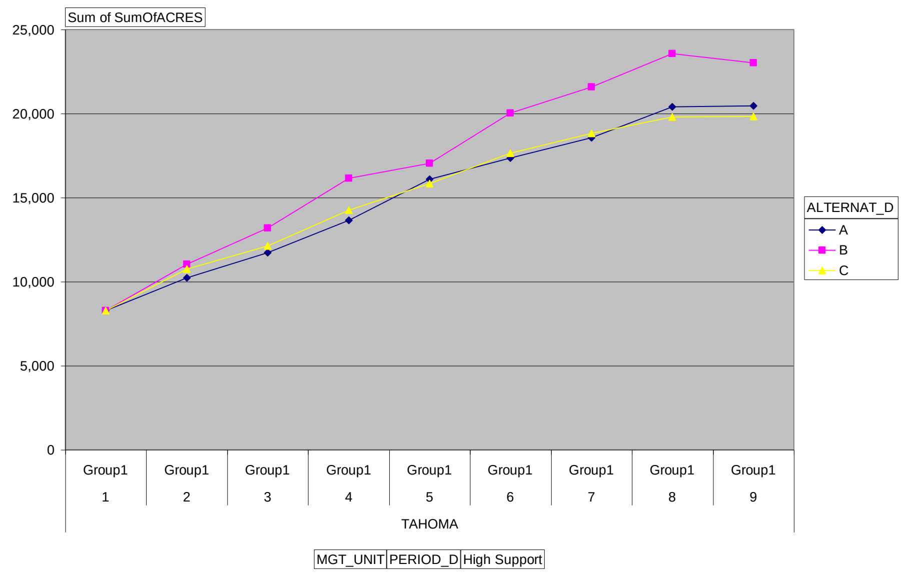
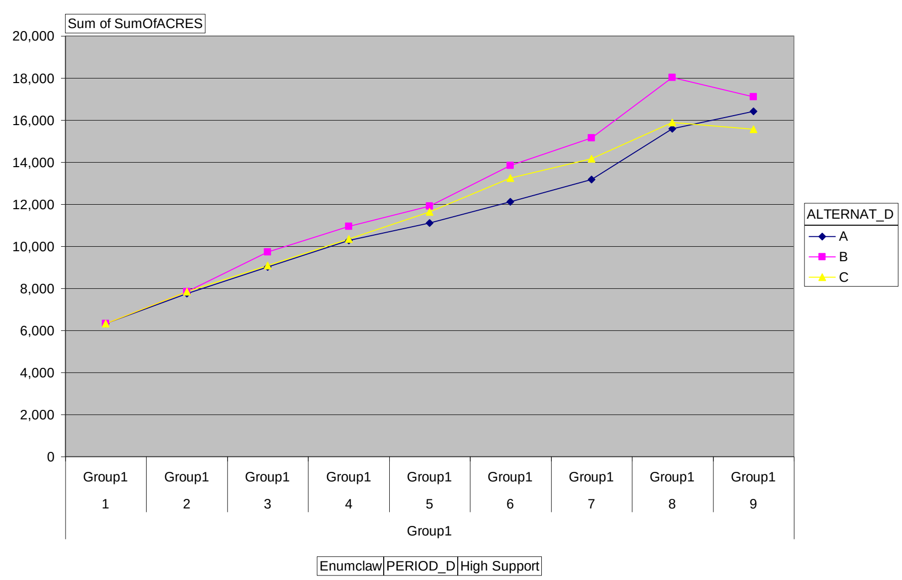


Chart G3-33 Tahoma Dispersal Management Movement Scores of High Support > 0.5



Black Diamond SOMUs

Chart G3-34 Grass Mountain Dispersal Management Foraging Scores of High Support > 0.5

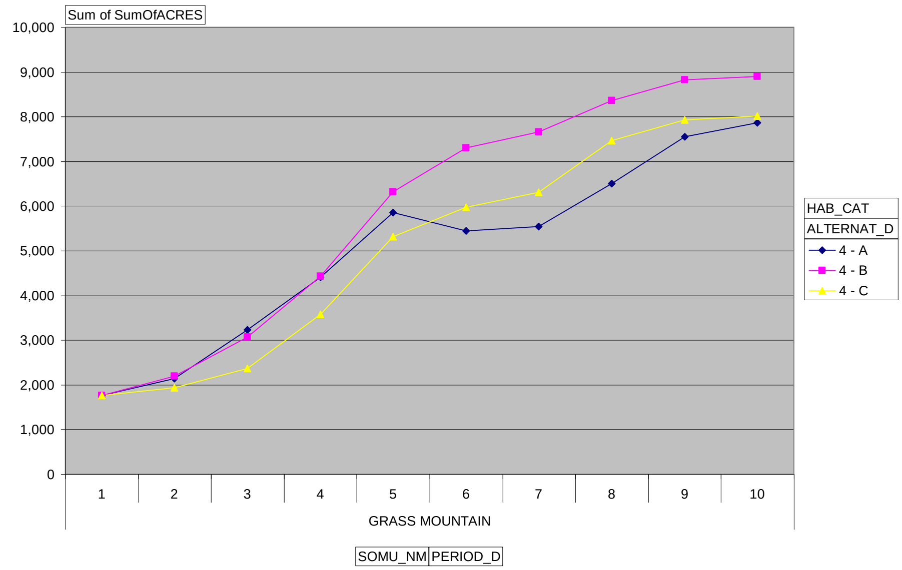


Chart G3-35 Grass Mountain Dispersal Management Roosting Scores of High Support > 0.5

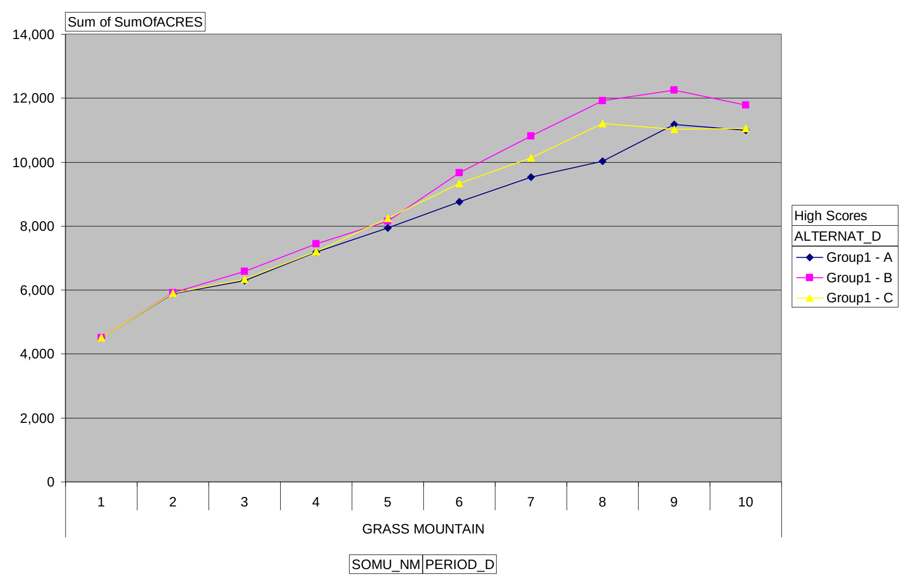
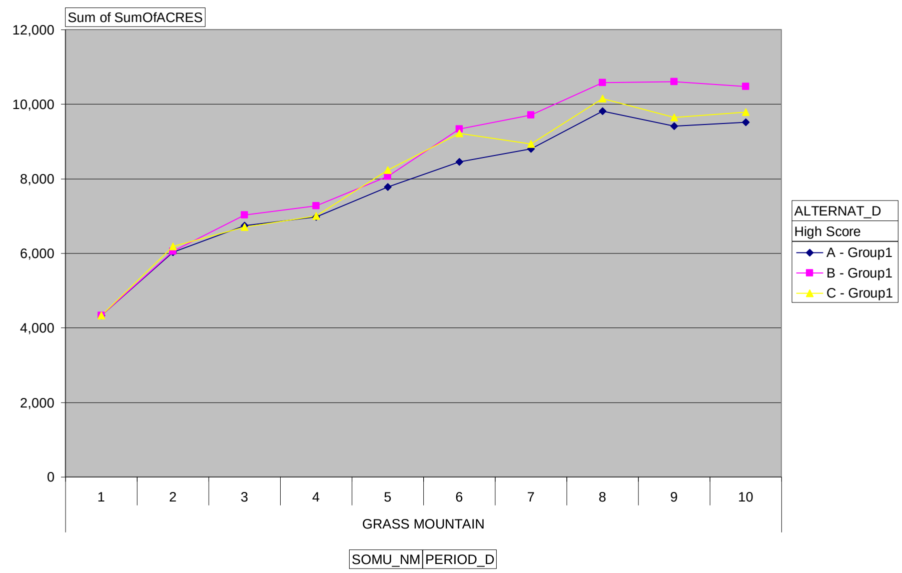


Chart G3-36 Grass Mountain Dispersal Management Movement Scores of High Support > 0.5



North Fork Green SOMU

Chart G3-37 North Fork Green Dispersal Management Foraging Scores of High Support > 0.5

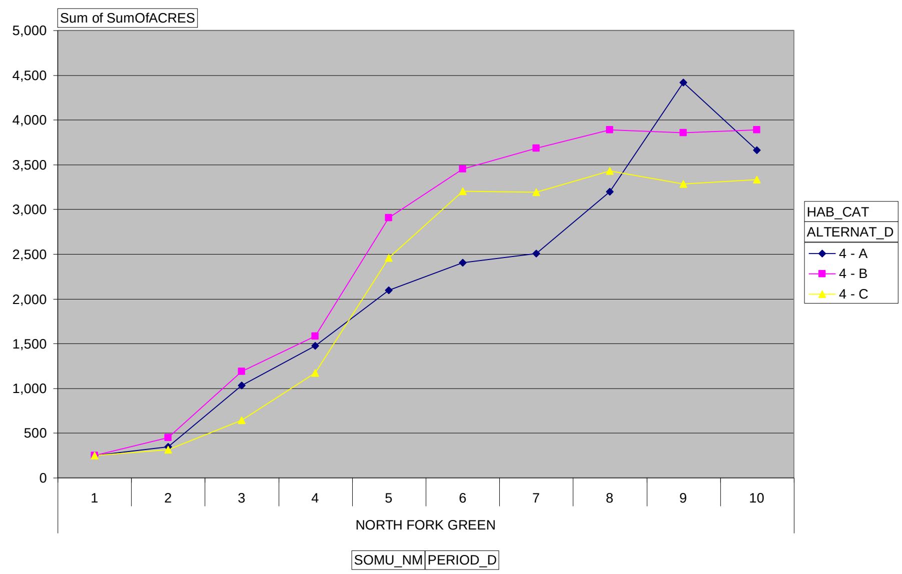


Chart G3-38 North Fork Green Dispersal Management Roosting Scores of High Support > 0.5

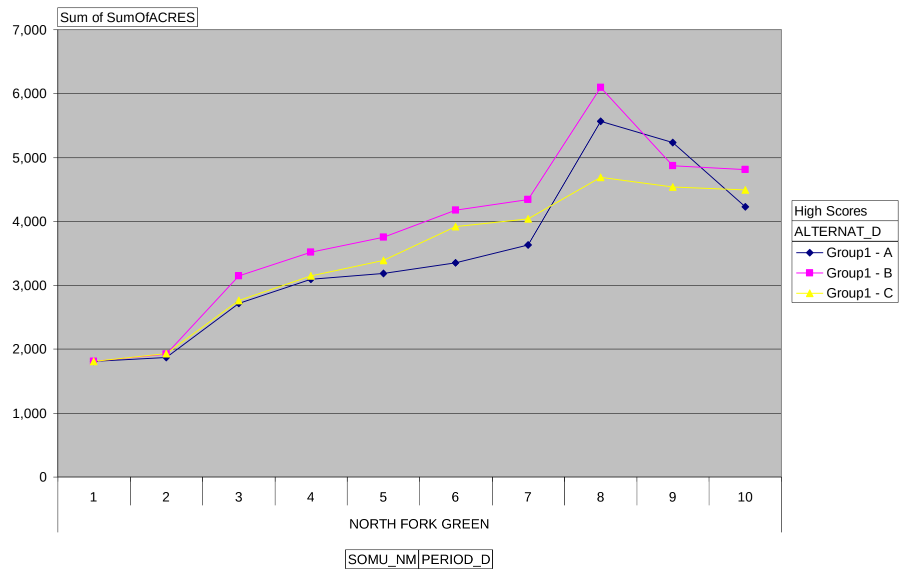
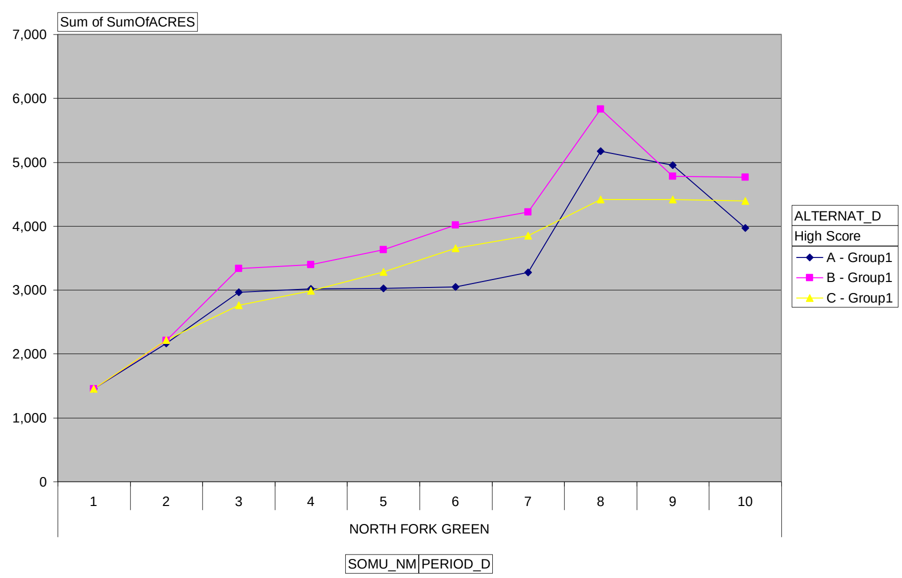


Chart G3-39 North Fork Green Dispersal Management Roosting Scores of High Support > 0.5



4: EMDS-DAT Landscape Dispersal Model

Introduction to the Landscape Model

The extent to which a landscape facilitates the dispersal of spotted owls is not only dependent on the habitat quality of stands and their size, but also on their spatial configuration. If habitat is only available clumped on one side of the management unit it is unlikely that owls will be able to successfully disperse to other areas on the management unit. This section describes a landscape-level modeling approach which builds upon the stand-level assessment models by considering the spatial arrangement of the evaluated DNR stands in relation to one another and adjacent non-DNR lands.

Owl Dispersal Biology

Although considerable research has been published on NSO habitat needs related to nesting, Buchanan (2004) noted only one published study that investigated landscape conditions used during natal owl dispersal. In this study, Miller (1997) identified two distinct phases of juvenile owl dispersal:

Transience: rapid movement through the landscape which typically occurs as young owls initially leave their natal sites in the fall, and again in the spring following a colonization phase

Colonization: short-term, non-territorial residences utilized by over-wintering juvenile owls.

The study found that dispersing owls used available habitat differently during these two phases (Table G4-1).

Table G4-1. Juvenile NSO habitat use during dispersal in proportion to (=), greater than (+), less than (-) abundance on landscape (adapted from Miller 1997)

Habitat Type	Transience	Colonization
Old-growth (>53.3cm [21in] DBH and <100% canopy closure 2 height classes, snags, down wood)	=	+
Closed sapling-pole-sawtimber (2.5-53.3cm [1-21in] DBH and >60% canopy closure)	=	=
Open sapling-pole (2.5-22.9cm [1-9in] DBH and <40% canopy closure)	-	-
Clearcut (< 2.5cm [1in] DBH and <40% canopy closure)	-	-

Forsman et al. (2002) conducted a second major study of dispersing juvenile owls. While they did not track habitat use, they measured movement rates and documented two major causes of owl mortality as predation and starvation. The Science Team built on these studies using their knowledge and experience to elaborate a basic conceptual framework for habitat assessment modeling. As a first principle, dispersing owls require adequate roosting and foraging opportunities as they move across the landscape. Second, owls have a limited ability to cross areas of unfavorable habitat. The level to which a landscape supports movement between suitable habitat patches is often referred to as connectivity. Roosting and foraging opportunities can be defined by the stand-level roosting and foraging model scores, while the connectivity between these areas can be determined from a combination of habitat patch distances and the stand-level movement model scores. The specific needs for habitat and connectivity also appear to vary by dispersal phase, as described below.

Transience

The Science Team characterized NSO habitat needs during the transience phase using a "stepping stones" concept. Because owls tend to move relatively rapidly and in random directions in this phase, the size of habitat patches is not as important as their distribution across the landscape. If owls are expected to be able to disperse across DNR lands, there must be sufficiently connected patches of roosting and foraging habitat spread across the landscape. Some potentially relevant estimates related to the transience phase from the literature are summarized below:

Miller (1989) observed juveniles moving an average of 1.6 km (0.75 mi) per day. Forsman et al. (2002) estimated average daily movements during transience at between 0.7 – 1.4 km (0.44 – 0.87 mi).

Beak (1993) defined a movement barrier as 0.4 km (0.25 mi) of non-dispersal habitat.

Lint et al. (2005) built on the Forsman et al. (2002) data and found juveniles moving from one nesting/roosting/foraging block to another block had an average total straight-line dispersal distance of 35 km (range: 8 – 116 km) or 22 mi (range: 5 – 72 mi).

Colonization

During the overwintering period, owls tend to remain in one place for a few months, requiring larger blocks of roosting and foraging habitat. Although there are no published estimates of what constitutes a sufficient patch size for overwintering, both patch size and quality are thought to be important for successful foraging and maintaining long-term energy budgets. Additionally, the amount of habitat edge (less is generally better) may influence exposure to predators and thermoregulation. The following are some potentially relevant measures from the literature:

Forsman et al. (2002) estimated average daily movements during colonization at between 0.4 – 0.6 km (0.25 – 0.37 mi).

A recent NSO modeling study in British Columbia (Sutherland et al. 2007) used a minimum patch size of 10 ha (25 acres), based on estimates of the home range of prey species.

Characterizing Habitat Connectivity

Connectivity can be broadly categorized as *structural* or *functional*. Examination of physical attributes such as size, shape and inter-patch distances are used to determine *structural* connectivity between habitat patches. In contrast, *functional* connectivity incorporates structural aspects of connectivity with organism behavior (e.g. dispersal information) to determine the connectivity of a landscape (With et al. 1997, Tieschendorf and Fahrig 2000). As an example illustrating the differences between structural and functional connectivity, two patches 100m apart are structurally unconnected, yet if an organism can cross the 100m span, then the two patches could be considered functionally connected.

While examinations of landscape structure can provide some insights into landscape patterns, structural connectivity alone does not meet the definition of landscape connectivity as defined by Taylor et al. (1993) because structural connectivity does not incorporate information on the dispersibility of the organism/population/species of interest. As illustrated in the example of the two patches 100m apart, structural connectivity measures may not accurately reflect the ability of an organism to move through a landscape. One of the most frequently used structural connectivity metrics involves nearest-neighbor measures (Moilanen and Nieminen 2002). The simplest form of such metrics examines the distance from a focal patch to the nearest patch. In essence however, all nearest-neighbor metrics only assess the distance to a neighboring patch without examining how other patches influence connectivity (Bender et al. 2003, Calabrese and Fagan 2004). In their meta-analysis of connectivity measures, Moilanen and Nieminen (2002) found nearest-neighbor measures performed poorly in their sensitivity to changes in connectivity. Thus, while the frequency with which nearest-neighbor metrics have been used likely relates to their simplicity and minimum data requirements, the authors concluded that such reasons were not adequate to justify their use. Because of limitations associated with structural-based measures of connectivity, we precluded their further use in measuring the ability of juvenile northern spotted owls to disperse through DNR ownership.

In their review and assessment of connectivity metrics, Calabrese and Fagan (2004) placed connectivity metrics into three general categories: *structural*, *potential*, and *actual* connectivity. While not explicitly defined as such by the authors, both potential and actual connectivity can be broadly viewed as types of functional connectivity. *Potential* connectivity incorporates structural aspects of the landscape with limited dispersal information (Calabrese and Fagan 2004). *Actual* connectivity is derived from studies that observed and/or tracked the movement of organisms across the landscape. Through the incorporation of structural and dispersal information, both potential and actual connectivity meet the spirit of landscape connectivity as originally defined by Taylor et al. (1993). Although detailed movement studies through methods such as telemetry and mark-recapture studies might provide the greatest understanding of movement and actual connectivity, they are expensive, labor intensive, and are difficult to implement at broad spatial scales (Calabrese and Fagan 2004). Because little information on natal northern spotted owl dispersal movement patterns and behavior is currently available, and surveys for owls are outdated, our ability to examine actual connectivity is limited.

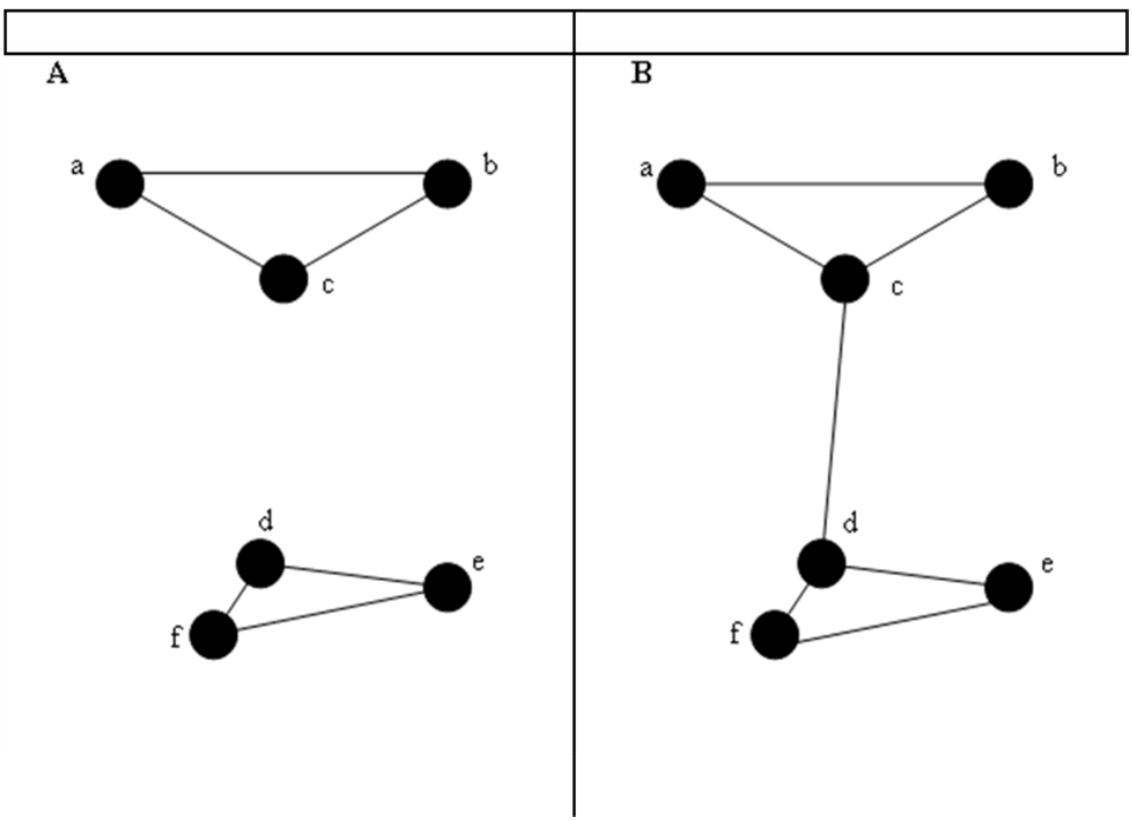
Since structural connectivity has been found to be of limited use in assessing landscape connectivity and there is a dearth of information on actual connectivity of dispersing juvenile northern spotted owls, we concluded that potential connectivity was the most appropriate method to assess our landscape. Examples of potential connectivity include buffer radius, incidence function metrics (IFM), and graph-theoretic measures (Calabrese and Fagan 2004). Both buffer radius and IFM's can incorporate actual patch occupancy information to determine potential connectivity. With the inclusion of patch occupancy information, the contribution of different patches to connectivity can be assessed. In buffer radius assessments, all occupied patches within a fixed distance from a focal patch are examined for connectivity. Connectivity is therefore based on area and number of occupied patches within the buffered radius (Calabrese and Fagan 2004). IFM's incorporate patch occupancy information, but also utilize a function describing how the probability of dispersal changes with distance (Calabrese and Fagan 2004). In the absence of patch occupancy information, Calabrese and Fagan (2004) suggested that both buffer radius and IFM metrics work in a similar fashion to graph-theoretic measures.

Graph theoretic measures have been suggested to possibly provide the "greatest benefit to effort ratio" (Calabrese and Fagan 2004) with respect to describing connectivity at broad spatial scales and in comparison to nearest-neighbor, buffer radius, IFM's, and actual dispersal assessments (Calabrese and Fagan 2004). Within the past decade, graph theory has been applied in the ecological literature to study a variety of species including the Iberian lynx (*Lynx pardinus*) in Spain (Ferreras 2001), ring-tailed lemur (*Lemur catta*) in Madagascar (Bodin and Norberg 2007), and the nymphalis butterfly (*Zygaena canniolica*) in Germany (Binzenhöfer et al. 2005). Bunn et al. (2000) examined connectivity for the American mink (*Mustela vison*) and prothonotary warblers (*Protonotaria citrea*) in North Carolina. They analyzed the same landscape but with different dispersal distance thresholds for each species. From the analysis, Bunn et al. (2000) concluded the landscape was connected for mink but not for prothonotary warblers. Fall et al. (2007) used spatial graphs to examine woodland caribou (*Rangifer tarandus caribou*) habitat with respect to the establishment of a national park in Manitoba, Canada. Keitt et al. (1997) and Urban and Keitt (2001) illustrated the utility of graph theory by assessing habitat connectivity for the dispersing Mexican spotted owl (*Strix occidentalis lucida*) in the southwest United States. Both studies demonstrated particular distance thresholds that created more fragmented (i.e. disconnected) landscapes from the perspective of the owl. Sutherland et al. (2007) used graph theory to assess the structural and functional connectivity of Northern Spotted Owl home ranges in British Columbia, Canada.

Given the advantages and disadvantages of connectivity metrics currently in use (Calabrese and Fagan 2004) and a dearth of information on dispersing owls, a graph-theoretic approach was applied to analyze landscape connectivity for dispersing juvenile Northern Spotted Owls.

Graph terminology
Graphs are composed of two basic elements, nodes and edges. In habitat studies the nodes are represented by habitat patches and edges are the distances between the patches. Urban and Keitt (2001) place graph-theoretic metrics into two general classes – node related and edge related measures. Ecologically, node related measures examine connectivity from the perspective of gains or losses in habitat due to natural or anthropogenic change. Edge related metrics examine changes in connectivity resulting from the addition or removal of paths between nodes. An edge will connect two nodes if the distance between two nodes is less than some distance threshold value (Figure G4-1A and G4-B). Nodes connected to each other through a series of edges but unconnected to other nodes are called *components* (Figure G4-1A and G4-B). No edges exist between nodes of different components and it is assumed that the species of interest can move within all nodes of a component but cannot move among nodes belonging to different components (Bodin and Norberg 2007). Figure G4-1 presents an example graph which illustrates different graph theory concepts. In figure G4-1A a relatively lower distance threshold was specified resulting in two components. Each component has three nodes and three edges. In figure G4-1B the distance threshold value was increased resulting in a single component with six nodes and six edges.

Figure G4-1. Example of Graph Theory Concepts



Using graph-theoretic measures, we pose a series of questions which use various edge and node related measures. The metrics were selected to aid policy and managers better understand how connectivity changes under different alternatives and assumptions.

Modeling Approach

The DNR landscape model uses a graph-theoretic approach which involves identifying suitable patches of roosting and foraging habitat (graph “nodes”) and calculating the distances (graph “edges”) between these patches. These distances are then compared to the estimated dispersal capability of the species to evaluate how well connected the landscape is by a particular configuration of patches. Following the lead of a number of recent studies (Bunn et al. 2000, Singleton et al. 2002, Theobald 2002), we incorporated the concept of varying “landscape permeability” (Singleton et al. 2002), that is, it costs more for the animal to move through areas of poor habitat than it does through areas of better habitat. Other terms used in the literature that relate to landscape permeability include landscape resistance and cost pathways.

Below is a summary of the steps used to create and assess the landscape for owl dispersal. Details of each step can be found in the sections which follow.

Summary of Steps

Compute stand scores for DNR-managed lands using the EMDS roosting/foraging/movement stand evaluation models on DNR inventory data.

Evaluate adjacent and interspersed non-DNR-managed lands using a parallel fuzzy logic model on a satellite imagery dataset.

Combine DNR and non-DNR lands into three raster layers (roosting, foraging, and movement—each composed of evaluated fuzzy scores).

Determine qualifying roosting/foraging habitat patches.

Assess connectivity between core habitat patches.

Compute landscape metrics

Step 1: Compute Stand Scores for DNR-managed Lands

The landscape modeling process begins by using the results of the stand-level models described in Section G1. These stand scores provide the input for identifying habitat patches and suitability for owl movement across the landscape.

Step 2: Evaluate Adjacent Non-DNR Lands

A fundamental premise behind dispersal habitat as defined in the WADNR HCP (1997) is that owls should be able to move across designated dispersal management areas to and from points outside DNR management. In addition, DNR-managed lands are bisected by and include in-holdings of other ownerships. Given our desire to model owl movements across the DNR-managed blocks, some integration of adjacent, non-DNR managed lands appears essential to the analysis.

Two basic approaches to modeling these lands were considered: 1) assume some uniform level of habitat quality (e.g. quality = 0), or 2) represent these lands using existing data. The current model used the latter approach in order to simulate connectivity with potential habitat on non-DNR managed lands. The best available source for land cover on surrounding non-DNR managed lands was classified satellite imagery (25 meter resolution) developed for the federal Northwest Forest Plan by the federal Interagency Vegetation Mapping Project (IVMP; O'Neil et al. 2002). This dataset is also being used for the current DNR marbled murrelet assessment.

The IVMP dataset is derived from images collected between 1992 and 1996. A change detection layer is available up to 2002; however, it was not used for this assessment since relatively few stands in the analysis area changed and it would require making assumptions about the resulting conditions of the stands. Further, it was not feasible to model the adjacent lands dataset into the future, since that would involve making assumptions about management on non-DNR lands and would considerably complicate the modeling effort. *Since these data are not current, their use is meant only to generally characterize conditions on non-DNR lands.*

Buffer Distance

The distance to extend the analysis into adjacent, non-DNR-managed lands is an important modeling consideration. Guidance could be derived from the owl dispersal distances, either the average (22 miles) or maximum (72 miles; Forsman et al. 2002) or the distances to adjacent federal lands (5-7 miles in the case of the McDonald and Grass Mountain blocks). However, the ultimate goal of this analysis is to specifically measure dispersal habitat *on DNR lands*, and buffers of these sizes would include far more non-DNR than DNR managed lands in the analysis area. A 1-mile buffer width was chosen for this analysis because this width spans ownership gaps within and between the DNR blocks. This distance also encompasses the maximum estimated connectivity distance (4,952 ft. / 1.4 km) described below.

Model used for Evaluating Non-DNR Managed Lands

Fuzzy logic models, comparable to the EMDS models for DNR-managed stands (see Section G1), were used to evaluate the IVMP data. Four indicators are available as part of the IVMP dataset: average tree size (quadratic mean diameter or QMD), percent conifer cover, percent broadleaf cover, and percent total vegetation cover. Broadleaf and vegetation cover were not used in the analyses because they include shrub and herb layers, which make them incompatible with the indicators chosen for the DNR stand models.

In consequence, the IVMP evaluation models rely on only measures of QMD and percent conifer cover. Conifer cover was used not as a canopy cover measure (it would be incomplete without hardwoods), rather as a surrogate for forest composition (the percent of the stand composed of conifers). QMD was used as a surrogate for top height. Given that there are only two indicators, the general model structures for the three objectives (roosting, foraging and movement) are identical: QMD and conifer cover scores are averaged to provide the overall score (see Figure G4-1). Furthermore, since the thresholds for these variables are the same in the EMDS roosting and foraging models for DNR lands, the IVMP roosting and foraging models are effectively identical to each other.   The movement model uses different thresholds. Tables G4-2 and G4-3 below detail the thresholds used for the combined roosting/foraging and the movement models. Since QMD is used as a proxy for tree height and canopy lift from the DNR models (roosting/foraging and movement, respectively), conversion processes are described following Table G4-2.

Figure G4-2. Non-DNR-Managed Lands Model Structure

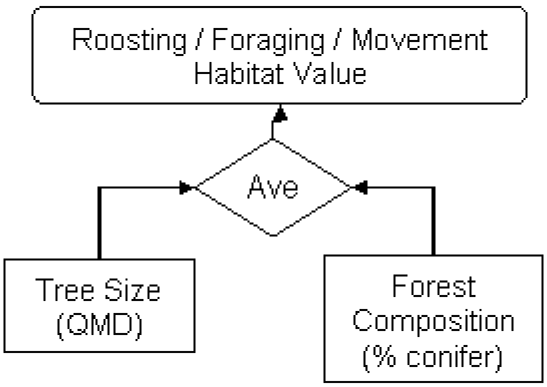
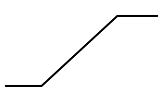


Table G4-2. Non-DNR-Managed Lands Roosting & Foraging Model Evaluation Criteria

Function Shape	Evaluated Score	Top Height (DNR Lands Model)	QMD Equivalent[1] (for IVMP model)
			
	1	120 Feet	22 inches
	-1	50 feet	11 inches

1. *Height to QMD conversion was done using equation 1 below.*

Table G4-3. Non-DNR-Managed Lands Roosting & Foraging Model Forest Composition Thresholds

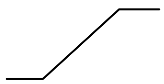
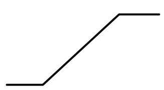
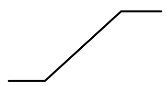
Indicator:	Forest Composition			
Function Shape	Evaluated Score	DNR Lands Model	IVMP Model	Units
				
	1	90	90	% conifer
	-1	50	50	% conifer

Table G3-4. Non-DNR-Managed Lands Movement Model Tree Diameter Thresholds

Function Shape	Evaluated Score	Stand Lift (DNR Lands Model)	Equivalent Stand Height[1]	QMD Equivalent[2]
				
	1	50 Feet	80 Feet	16 inches
	-1	30 Feet	50 Feet	11 inches

1. *Lift to height conversion was based on previous estimates from the WADNR HCP (1997 p. IV-25; note these estimates were for eastside forests).*
2. *Height to QMD conversion was done using equation 1 below.*

Table G4-4. Non-DNR-Managed Lands Movement Model Forest Composition Thresholds

Indicator:	Forest Composition			
Function Shape	Evaluated Score	DNR Lands Model	IVMP Model	Units
				
	1	80	80	% conifer
	-1	30	30	% conifer

The following formula for converting from stand height used in the DNR model to the QMD measure available in the IVMP data (both for the top 40 trees in the stand) was estimated using a linear regression (R^2 = 0.83) on the DNR inventory data:

Equation 1.

Tree height to QMD conversion

$$QMD40 = 4.03 + 0.15 * HT40$$

Step 3: Combine DNR and non-DNR Data

Since roads were clipped out of the forest growth and yield stand map layers, a way was needed to re-integrate these areas into the landscape. The NSO Science Team did not believe that roads posed any special dispersal difficulty for owls, but since they are cleared areas roads were assigned a habitat score of 0 (equivalent to a clearcut).

Next, in order to assess DNR-managed lands in a landscape context, the DNR stand scores were overlaid on the evaluated non-DNR data (IVMP). The DNR stand data are converted from a polygon to a raster (pixel-based) map using the $25m^2$ resolution (pixel size) of the IVMP data.

Step 4: Determine Core Habitat Patches

Habitat Quality Threshold

Since the graph-theoretic approach is based on connecting nodes (i.e. patches) via edges (i.e. paths between patches), some method of determining what constitutes a patch was needed. The NSO Science Team reasoned that as owls move across the landscape, they will need opportunities for both roosting and foraging. They chose a stand-level model score of ≥ 50 for both roosting and foraging as the threshold for designating habitat patches. The threshold of 50 is consistent with the definition of the stand-level model scores, where scores greater than 50 signify a preponderance of evidence that the habitat is sufficient to meet roosting and foraging requirements.

Functional Patches

The FunConn tool (Theobald et al. 2006), which served as a basis for our process, recognizes that for many species "potentially functional" patches are better defined by available habitat within some foraging distance, rather than requiring all habitat forming a patch to be immediately adjacent. This view appears consistent with descriptions from the Science Team. While there are a number of studies which have examined the foraging distances exhibited by nesting adults, there is a dearth of such information related to juvenile dispersal. Based on one in-progress study, the expert group estimated this foraging distance at 1,312 ft. (400 m.), which is also consistent with some current HCP definitions (Buchanan 2004). This foraging distance was applied to the movement model resulting in an effective distance of 200-400m depending on the quality of the intervening habitat (described under the "Movement Layer" section)

Minimum Patch Size

Although territory sizes have been estimated for nesting owls (Forsman et al. 1984), no similar research has been found on minimum patch size used by dispersing juveniles. A recent owl modeling study by Sutherland et al. (2007 p. 31) chose a ten hectare (25 acre) minimum based on expert judgment of the home range size of primary prey species. The Science Team did not believe that such a requirement was justified and thought that dispersing owls could use any available habitat of sufficient quality, at least down to our minimum mapping unit of $25m^2$. While single pixels of habitat occur on non-DNR managed lands (as an artifact of the satellite imagery), such small areas are unlikely on DNR-managed lands because these lands are mapped and treated as larger stand units (with an average size of 6 acres or 2.4 hectares).

Step 5: Calculate Potential Connectivity Between Core Patches

The potential connectivity of the roosting/foraging habitat identified in the previous step is assessed by choosing a base distance that owls are assumed to be able to travel (a "connectivity distance") and the relative effects of different landscape features/covers on this distance (a "movement layer").

Connectivity Distance

Connectivity distance refers to the distance a dispersing organism is likely to travel. This connectivity distance is used to determine if two habitat patches are connected from the perspective of the organism. Some studies have taken a macro approach to dispersal by setting connectivity around the average total dispersal range of the species (Keitt et al. 1996; Singleton et al. 2002). However, since the dimensions of entire DNR-managed blocks are smaller than the NSO dispersal range, a smaller scale assessment would be more useful for this analysis. Information on average daily movement rates was used to examine the ability of the landscape to meet owl roosting and foraging needs on a daily basis. Forsman et al. (2002) found that average daily movement ranged from 4,592 ft. (1.4 km) during the transience phase to 1,312 ft. (0.4 km) during colonization. Miller et al. (1997) calculated an average rate of 1 mi.

(1.6 km) per day. Note, however, that these are net distances derived from multi-day averages (and owls are probably not flying in a straight line) and these distance measures did not consider habitat quality.

Movement Layer
A number of habitat modeling efforts have begun to recognize that habitat accessibility is not only influenced by distance but also by the character of the intervening landscape matrix (Singleton et al. 2002; Theobald 2002, 2006; Theobald et al. 2006; Bunn et al. 2000, Urban and Keitt 2001). Thus, rather than modeling all matrix as non-habitat, stands in the matrix had an array of values in recognition that the matrix also varied in quality (Lindenmayer and Franklin 2002). One method of incorporating variation in matrix quality is through the use of a resistance surface (also known as a permeability or cost-distance surface), which is in essence a multiplier applied to the actual (Euclidean) distance on the ground. Resistance values are assigned to landscape features which impede or otherwise discourage movement of a particular species, such as roads, water bodies, slope, or urbanized lands. Little research is available on barriers to owl movement, but the NSO Science Team recognized that non-forested areas exposed owls to greater predation risk and very dense stands could impede their movement. These factors are incorporated into the stand-level movement model (see Section F1), and the resulting scores are used here to generate resistance values used in the landscape model.

The studies cited above all used mathematical functions to convert habitat scores to resistance values, but the formulation of these functions varied considerably (one was linear, the other logarithmic). Because little is known about barriers to owl movement, a simple linear function was chosen, and because it appears that owls cross areas of poor habitat, a small range was chosen for the resistance multiplier. Equation 2 and Table G4-5 below describe a function which produces a minimum multiplier of 1.0 for the best movement habitat (movement score = 100) to a maximum multiplier of 2.0 for the worst movement habitat (score = 0). Table G4-5 also shows the cost to traverse a 25m^2 unit (cell) of the landscape and the maximum distance an owl could traverse given the connectivity distance of 1.4 km.

Equation 2. Resistance Multiplier

Resistance Multiplier = 2 – Movement Score / 100

Table G4-5. Movement Score, Resistance, Cell Cost, and Cell Movement Equivalents

Movement Score	Resistance Value	Cell Cost[1]	Max Distance[2]	
			ft	m
100	1	82	4,592	1,400
90	1.1	90	4,174	1,273
80	1.2	98	3,826	1,166

70	1.3	107	3,532	1,077
60	1.4	115	3,280	1,000
50	1.5	123	3,061	933
40	1.6	131	2,870	875
30	1.7	139	2,701	823
20	1.8	148	2,551	778
10	1.9	156	2,416	737
0	2	164	2,296	700

1. *Cost to traverse across one 82 ft^2 (25 m^2) cell.*
2. *Maximum distance traversable in this quality habitat given a connectivity distance of 1.4 km.*

The Science Team surmised that open water was likely to be a more significant barrier given the total lack of potential cover, and so a GIS layer of major water features was overlaid on the movement resistance map and all water features were given a resistance multiplier of four.

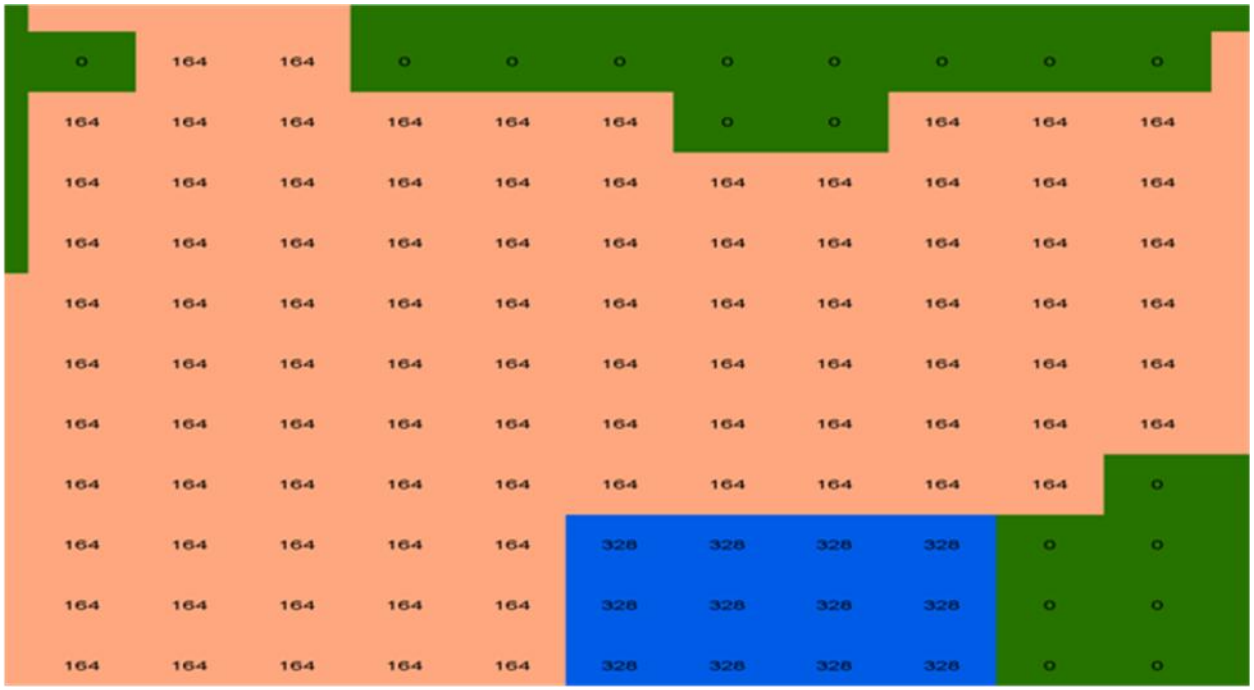
Connectivity Model

The connectivity of roosting and foraging habitat across the landscape was calculated using a modified version of the Build Landscape Networks script from the Functional Connectivity extension for the ArcGIS software (aka FunConn; Theobald et al. 2006). This script uses the COSTDISTANCE command to grow the initial habitat patches (stands with roosting and foraging scores ≥ 50) out through a resistance layer (as determined by the resistance function above). As the COSTDISTANCE function moves out from the habitat patches, each cell is assigned a score that is the cumulative total of the cell resistance values crossed.

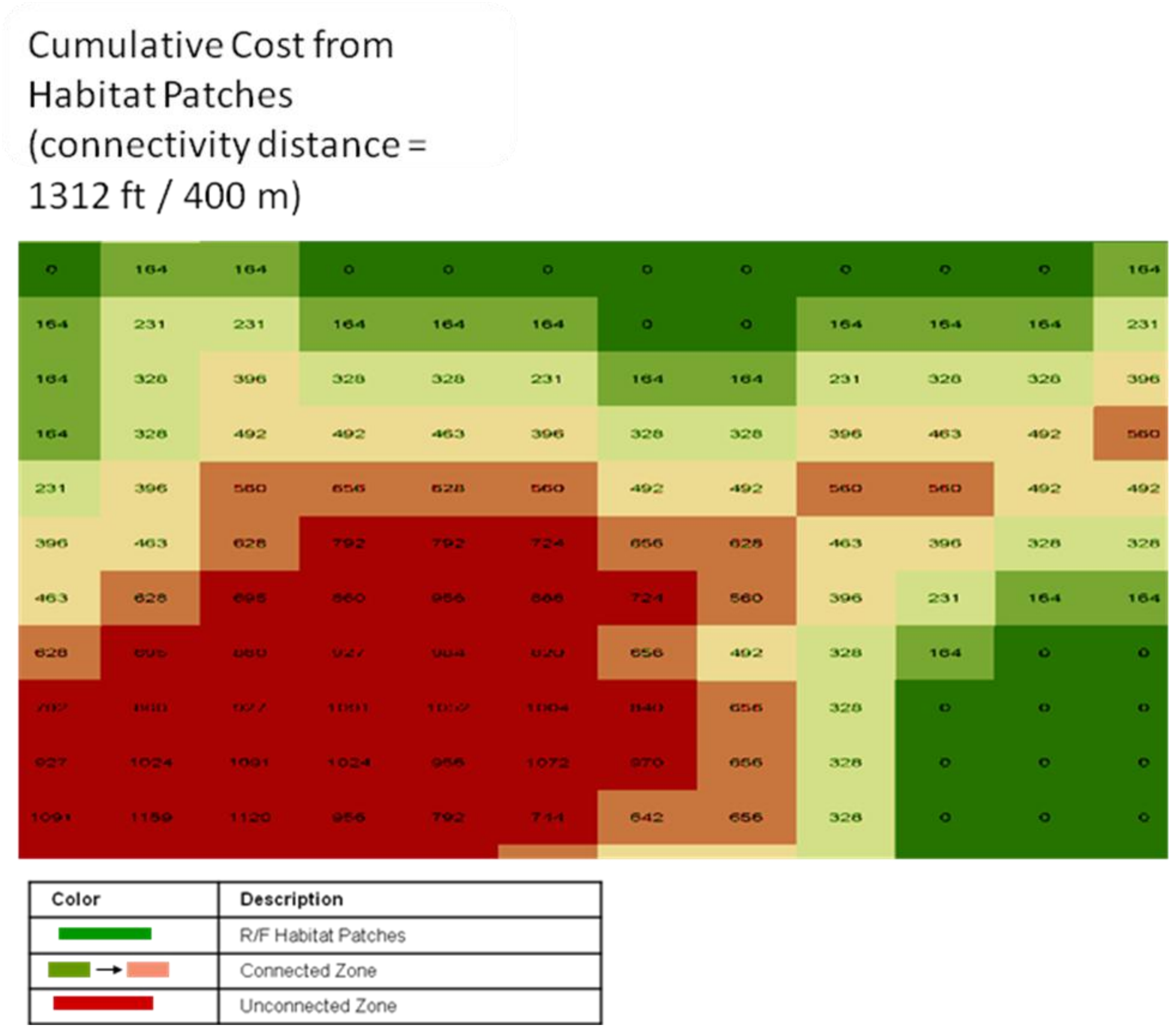
Some studies have used the least cost path (a common GIS function) between each pair of patches as the interpatch distance. However, Theobald (2006) notes that animals are unlikely to always discern and use such maximally efficient paths. Rather, they may disperse from a patch at any point and in any direction. He therefore proposed using a broader sampling of the many potential paths as the interpatch distance rather than the least-cost path. Following this approach, this model calculated the interpatch distance as the average distance between each set of adjacent patches. As the cost surface is grown out from a patch, it encounters surfaces growing out from other patches. The lines formed by the meeting of these surfaces are called the allocation boundaries (also known as thiessen or voronoi polygons). The average cost along each of these boundaries provided the interpatch distances.

Figure G4-3. An example of how the COSTDISTANCE function accumulates scores between two core habitat patches and the resulting allocation boundaries

Individual Cell Costs =
Distance (82 ft) X
Resistance (0-4)



Color	Description
	R/F Habitat Patches
	Clearcut (2 X)
	Water (4 X)



Landscape Metrics of NSO Dispersal Support

The final step in the assessment process is to summarize the data using landscape metrics to assess habitat quantity, quality, and configuration. Such an assessment can indicate the influence of different policies on the life history needs of dispersing owls. Pascual-Hortal and Saura (2006) compared many common indices used in the graph-theoretic literature and also proposed a new index called the Integral Index of Connectivity (IIC). IIC was used in this analysis for the following reasons: it is a bounded index from zero to one, it incorporates the total landscape area and therefore incorporates both habitat and non-habitat in the assessment, and the metric reacts in a consistent fashion with gains and reductions in patch area and number of edges.

Equation 33 below shows the IIC formula, where a_i and a_j are the "effective" areas of habitat patches *i* and *j*. Effective area incorporates both habitat quality and patch area into a single metric in recognition that patches with lower quality are not equivalent to patches of the same size but of higher habitat quality. Effective area is calculated as the actual area multiplied by the average stand habitat score of the patch. Given the chosen connectivity distance, nl_{ij} is the number of links (or edges) in the shortest path between patch *i* and patch *j*. A_L represents the area of the analysis landscape.

Equation 3. Integral Index of Connectivity (IIC)

$$IIC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{a_i \cdot a_j}{1+nl_{ij}}}{A_L^2}$$

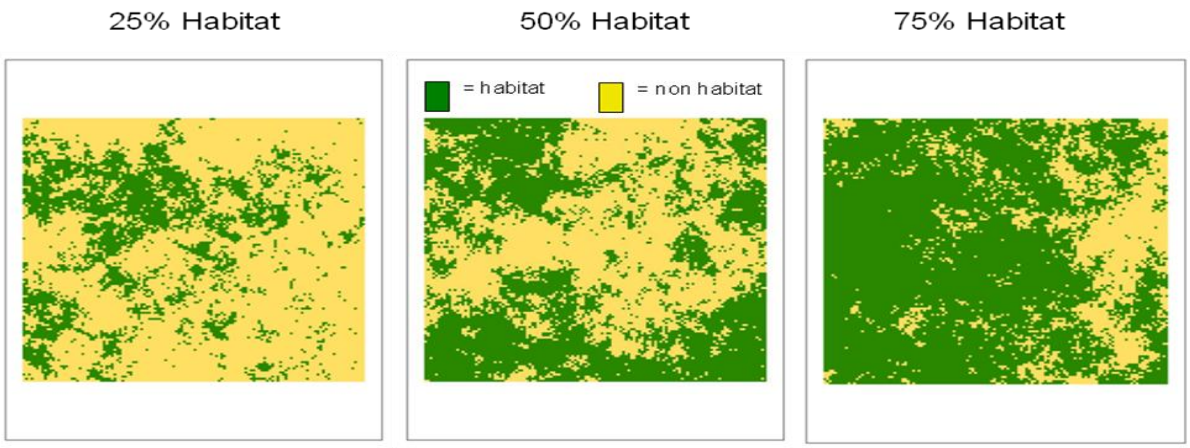
Maps of resulting habitat patches and IIC scores for the alternatives over time are presented in Chapter 4. Two additional graph theory-based measures, the number of edges (NE) and number of components (NC), are reported briefly below (Tables 7 and 8). NE stands for the total number of edges between habitat patches in a landscape within a given dispersal distance. NC is the total number of components (defined in the Graph Terminology section above) in the landscape. These landscape statistics are also analyzed at two connectivity distances: 4,592ft (1400m) representing the average daily movement rate during the transient phase, and 1,312ft (400m) representing the average daily movement rate during the colonization phase.

Neutral Landscape Model Results

One way of better understand how NE, NC and IIC respond to changes in habitat is through the examination of neutral landscape models. For this study, neutral landscape models are random maps of habitat and no habitat where the amount and configuration of habitat can be controlled. For this analysis, maps depicting 25, 50, and 75% habitat were created. Each habitat map was depicted under three different configurations (dispersed habitat, moderately clumped habitat, highly clumped habitat) for a total of nine habitat maps. For each map, NE, NC, and IIC scores were calculated. These metrics were calculated using three arbitrary dispersal distances: 10, 100, and 300m. All maps were generated in the software RULE (Gardner, 1999) and each map was approximately 310m in length and width. Euclidean, rather than cost, distances were implemented to examine distances between patches.

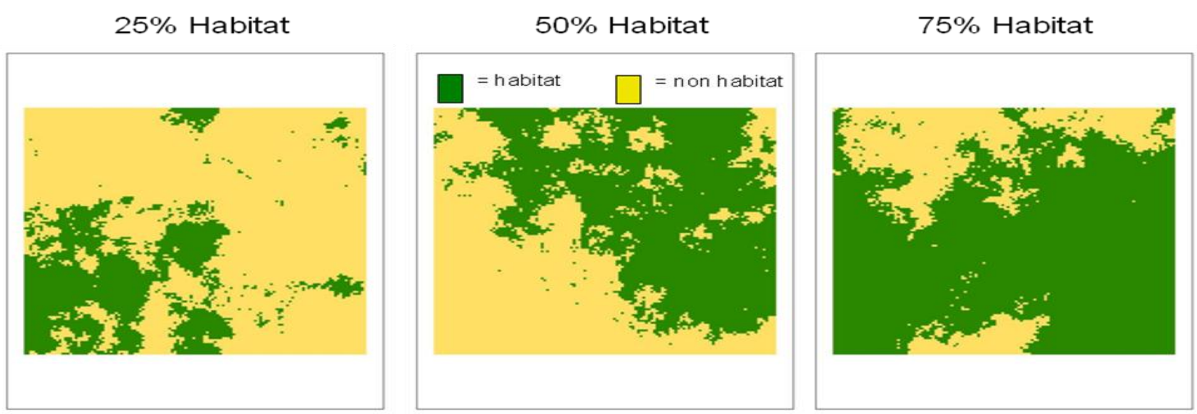
As dispersal distances increase, the number of edges should increase, the number of components decrease, and IIC should remain constant or increase in value. These responses are expected because as the distance an organism can move increase, more patches become connected. As more patches become connected (NE increases), fewer and larger components are present (NC decreases) in the landscape, all of which can cause IIC scores to increase. These trends can be seen for all random maps (Figures G4-4, G4-5, and G4-6).

Figure G4-4 Neutral Landscape of Dispersal Habitat



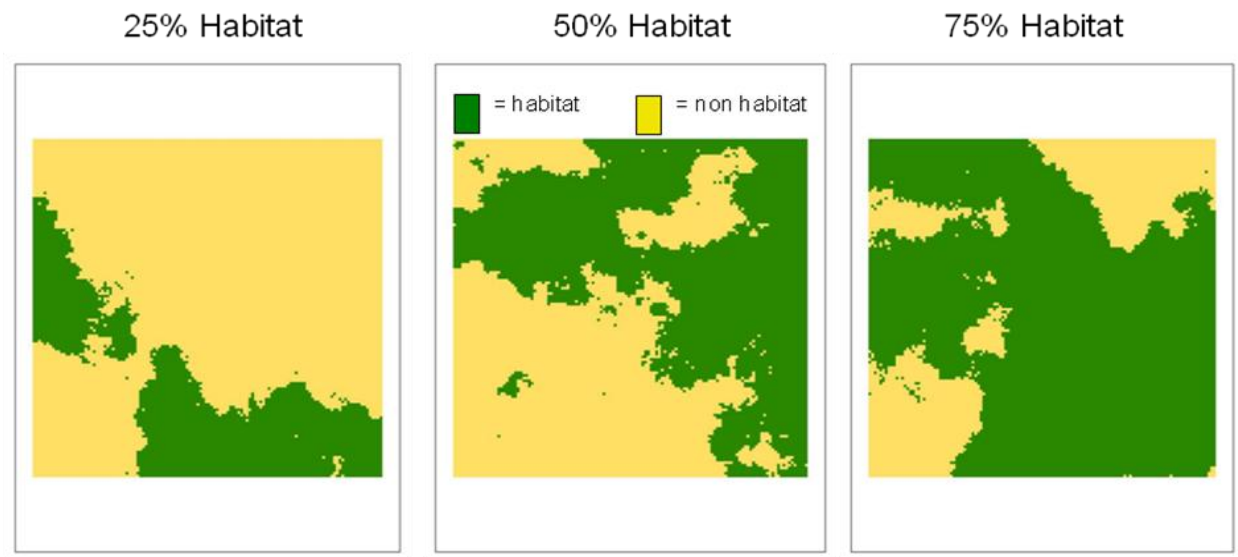
Distance (m)	NE	NC	IIC	NE	NC	IIC	NE	NC	IIC
10	214	313	0.01	225	214	0.05	116	65	0.52
100	1155	38	0.02	1026	8	0.11	415	2	0.53
300	5098	1	0.03	4185	1	0.13	1320	1	0.53

Figure G4-5. Neutral Landscape of Moderately Clumped Habitat



Distance (m)	NE	NC	IIC	NE	NC	IIC	NE	NC	IIC
10	53	102	0.04	30	57	0.25	43	53	0.57
100	254	17	0.04	99	15	0.26	155	7	0.58
300	797	6	0.04	275	2	0.26	476	1	0.58

Figure G4-6. Neutral Landscape of Highly Clumped Habitat



Distance (m)	NE	NC	IIC	NE	NC	IIC	NE	NC	IIC
10	13	16	0.04	14	29	0.25	17	16	0.58
100	35	5	0.04	55	7	0.25	54	4	0.58
300	77	1	0.05	125	4	0.25	122	1	0.58

As the amount of habitat increases, the results from the neutral landscapes suggest NC will tend to decrease. This trend can be observed in Figure G4-4. In the figure, as the amount of habitat increases, NC for a 10m dispersal distance decreases from 313 components at 25% habitat to two components at 75% habitat. IIC tends to increase as habitat increases within a given dispersal distance and habitat configuration (dispersed habitat, moderately clumped habitat, highly clumped habitat). This trend is in part explained due to IIC values increasing as the total amount of habitat in the landscape grows, but is also due to patch configuration. It should however be noted that IIC scores for 50 and 75% habitat in both moderately and highly clumped configurations (Figures G4-5 and G4-6) exhibit modest changes. Because of the habitat configurations, most available habitat is already connected within a 10m dispersal distance. As a consequence, increasing the dispersal distance does not add many habitat patches of large area and thus leads to minimal increases in IIC scores. Furthermore, while IIC can range from zero to one, a score of one can only be reached if the entire landscape is composed of habitat (a single large patch). Because the amount of habitat is 25, 50, or 75% for the neutral landscapes, IIC scores will never receive a full value of one. Thus, although there is only one component for 75% habitat and a dispersal distance of 300m in Figure G4-5 indicating all habitat is connected, the IIC value plateaus at 0.58. Similarly, the IIC value never exceeds 0.03 for 25% habitat in Figure G4-4 because although all habitat patches are connected (NC=1), there is so little habitat relative to the entire landscape extent that IIC scores remain low.

The pattern for NE is less consistent across the different habitat configurations. For example, NE tends to decrease under the dispersed habitat configuration (Figure G4-4) as the amount of habitat increases. Conversely, as the habitat becomes more clumped in configuration (Figures G4-5 and G4-6), NE sometimes increases as the amount of habitat increases and sometimes decreases as the amount of habitat increases. These inconsistent patterns illustrate that NE is not an adequate indicator of habitat trends in and of itself, but NE can illuminate patterns when placed within the context of NC and IIC. As an example, NE fluctuates from 53 to 30 to 43 as habitat increases from 25 to 75% (Figure G4-5) at a 10m dispersal distance. Such changes in NE do not indicate meaningful overall landscape patterns. By also examining NC and IIC scores, it becomes clearer that habitat patches are becoming better connected (decreasing NC) and increasing in area (increasing IIC). It can therefore be concluded that the variation in NE with the amount of habitat is likely due to the presence of small patches at 75% habitat that are not present with 50% habitat.

Shifting from results of neutral landscapes to results from EMDS-DAT model, the following trends would therefore be expected:

As dispersal distances increase

The number of edges will increase.

The number of components will decrease.

IIC scores will remain constant (if all patches already connected) or increase, but never reach the maximum value of one.

As the amount of habitat increases

The number of components will decrease.

IIC scores will increase but never reach the maximum value of one.

DNR Landscape Results
Chapter 4 presents summary charts and discussion for the IIC scores over time for the three alternatives.

Table G4-6 summarizes the number of components present in the two landscapes in all of the alternatives and time periods for the two connectivity distances chosen. Given the 4,952ft (1400m) connectivity distance, the patches in both the Black Diamond and Elbe-Tahoma landscapes are connected into just 3 overall groups in the initial period. That NC is low and changes little through time suggests both landscapes were well connected beginning in the first time period. Although the available habitat was mostly connected, the amount of available habitat relative to the total landscape sizes (both DNR and non-DNR lands) was limited, likely resulting in IIC scores increasing and then essentially leveling off. Given the trends in NC and IIC scores, the number of edges (NE,

Table G4-7) probably decreased because existing habitat patches coalesced into larger patches through time and therefore fewer edges were needed to connect habitat patches. These trends were consistent across both landscapes and all alternatives.

With the smaller 1,312ft (400m) dispersal distance, fewer patches were connected to other patches resulting in greater NC values than reported under a 1400m dispersal distance. Similarly, with fewer connected patches, the total number of edges was less than under a greater dispersal distance. Although the number of components was greater and the number of edges fewer, IIC scores were not very different at 400 or 1400m. Again, these trends appeared fairly consistent across alternatives and landscapes.

Table G4-6. Number of Components (NC)

		Distance (m)					
			400m			1400m	
		Alternatives			Alternatives		
Landscape	**Period**	**A**	**B**	**C**	**A**	**B**	**C**
Black	1	76			3		
Diamond	2	72	73	73	5	5	5
	3	69	68	69	5	5	6
	4	66	60	60	4	4	4
	5	59	55	57	4	4	4
	6	54	52	51	4	4	4
	7	46	47	48	4	4	4
	8	44	47	47	4	4	4
	9	45	48	49	4	4	4
	10	45	48	48	3	3	3
Elbe-	1	110			3		
Tahoma	2	100	100	101	4	2	2
	3	84	82	81	2	2	2
	4	81	78	79	2	2	2
	5	74	73	73	2	2	2
	6	71	66	70	2	2	2
	7	65	65	70	2	2	2
	8	64	64	67	2	2	2
	9	67	67	67	2	2	2
	10	68	68	68	2	2	2

Table G4-7. Number of Edges (NE)

		Distance (m)					
			400m			1400m	
		Alternatives			Alternatives		
Landscape	Period	A	B	C	A	B	C
Black	1	28			169		
Diamond	2	29	29	29	161	160	162
	3	30	29	27	152	151	151
	4	30	29	28	154	145	145
	5	31	29	28	151	140	143
	6	30	26	25	138	128	126
	7	27	24	25	120	117	120
	8	25	25	26	110	115	116
	9	25	23	24	113	115	119
	10	23	24	25	110	119	120
Elbe-	1	42			257		
Tahoma	2	42	42	44	238	245	254
	3	41	45	46	213	214	213
	4	41	42	45	201	200	211
	5	41	41	41	193	192	192
	6	38	43	41	179	180	181
	7	39	40	39	170	172	176
	8	41	41	40	172	172	173
	9	40	40	40	174	174	173
	10	38	39	39	172	173	173

Conclusions
Similar to the IIC results presented in Chapter 4, the differences found in the numbers of components and edges measures between alternatives was small. Both the number of components and edges trended down over time as the landscapes became increasingly filled with dispersal habitat. Cumulatively, these results reinforce the conclusion that habitat quantity and connectivity improved with time. As indicators of the relative value of the alternatives, however, component and edge counts were even less discerning that the overall IIC index.

In contrast to the IIC results, differences in components and edges between the 1400m and 400m connectivity distances were large. At the 1400m distance the landscapes became connected into just a few components (2 – 5), usually dominated by one large cluster with a few additional small outliers (as shown in maps in Chapter 4). At the 400m connectivity distance, however, the number of components was much greater (45 – 110).

An analysis of why the IIC scores did not show such a difference between the two connectivity distances revealed that the IIC score became dominated by the influence of one large non-DNR patch in the Black Diamond landscape and one large DNR-managed patch in the Elbe-Tahoma landscape. The Index not only calculates the area of two connected patches (a_i and a_j), but also the area of each individual patch ($a_i = a_j$, a patch connected to itself). Therefore, because each patch area is squared in the numerator of the IIC equation (when $a_i = a_j$), the one large patch greatly influenced the IIC score at both connectivity distances.

Areas for Future Research and Development
For convenience, a summary of the key parameters used in the landscape model is presented in

Table G4-8. The modeling team used this summary and experienced gained in the process to identify a few high priority development areas.

First, since the landscapes in this analysis are designated to provide support to owls moving across DNR-managed lands to other areas, this analysis incorporated non-DNR habitat within a one mile buffer. This buffer, however, ends up comprising approximately half the landscape area analyzed by the model. Since these non-DNR lands are not modeled, they tend to obscure management differences on DNR-managed lands. Methods to assess outside connectivity without including such a large proportion of non-DNR lands will be investigated.

Second, the NSO Science Team recommended giving developed lands a greater resistance multiplier in the movement model. However, no appropriate development layer was found in time to incorporate into the model. The next iteration of the model could potentially include a development layer available for DNR-managed lands, along with development indicated in the GAP analysis layer for other lands.

Finally, it appears worthwhile to continue to investigate additional landscape metrics and graph-theoretic measures to better assess landscape connectivity.

Table G4-8. NSO Landscape Model Key Parameters Summary

Parameter	Value	Rationale
Distance to look into non-DNR lands	1 mi	Cover gaps between DNR parcels
Non-DNR lands roosting/foraging model	QMD 11-22” ForCmp 50-90%	EMDS stand model equivalents
Non-DNR lands movement model	QMD 11-16” ForCmp 30-80%	EMDS stand model equivalents
Map resolution (pixel size)	82 ft^2 ($25m^2$)	Resolution of IVMP layer
Minimum score/quality necessary to be core roosting/foraging habitat	EMDS 0 (50/100)	Point where evidence for habitat becomes positive
Roosting/foraging combination method for identifying core habitat	Direct overlap	Patch must provide both to be core patch
Minimum size necessary to be core roosting or foraging habitat	None	Science Team decision
Habitat connectivity distance (maximum traversal distance between core patches)	1312 ft (400m) 4496 ft (1400m)	Average daily movement rates during colonization & transience phases (Forsman et al. 2002, Fig. 6)
Habitat score to resistance score conversion function	RV = 2 - [Movement]/100 RVwater = 4	Connectivity reduced up to 50% by adverse habitat

REFERENCES

Beak Consultants Inc. 1993. Habitat conservation plan for the northern spotted owl on timberlands owned by the Murray Pacific Corporation. Murray Pacific Corporation. Tacoma, WA.

Binzenhöfer, B., B. Schröder, B. Strauss, R. Biedermann, and J. Settele. 2005. Habitat models and habitat connectivity analysis for butterflies and burnet moths – The example of *Zygaena carniolica* and *Coenonympha arcania*. Biological Conservation 126: 247-259.

Bodin, O. and J. Norberg. 2007. A network approach for analyzing spatially structured populations in fragmented landscapes. Landscape Ecology 22: 31-44.

Buchanan, J. B. 2004. Managing habitat for dispersing northern spotted owls--are the current management strategies adequate?. Wildlife Society Bulletin 32(4):1333-1345.

Bunn, A.G., D.L. Urban, and T.H. Keitt. 2000. Landscape connectivity: a conservation application of graph theory. Journal of Environmental Management 59: 265-78.

Calabrese, J.M. and W.F. Fagan. 2004. A comparison-shopper's guide to connectivity metrics. Frontiers in Ecology and the Environment 2: 529-536.

Fall, A., M.-J. Fortin, M. Manseau, and D. O'Brien. 2007. Spatial graphs: principles and applications for habitat connectivity. Ecosystems 10: 448-461.

FEMAT. 1993. Forest Ecosystem Management: An Ecological, Economic and Social Assessment. USDA Forest Service, BLM, USFWS, NOAA, EPA and National Park Service. Portland, Oregon.

Ferreras, P. 2001. Landscape structure and asymmetrical inter-patch connectivity in a metapopulation of the endangered Iberian lynx. Biological Conservation 100: 125-136.

Forsman et al. 2002. Natal and breeding dispersal of northern spotted owls. Wildlife Monographs 149.

Gardner RH (1999) RULE: A program for the generation of random maps and the analysis of spatial patterns. In: Klopatek JM, Gardner RH (eds) Landscape ecological analysis: issues and applications. Springer-Verlag, New York, pp 280–303.

Keitt, T. H., A. Franklin, and D.L. Urban. 1996. Landscape analysis and metapopulation structure. Chapter II.3 in USDI Fish and Wildlife Service, Recovery Plan for the Mexican Spotted Owl: Vol.I., Albuquerque, NM. 172pp.

Keitt, T.H., D.L. Urban, and B.T. Milne. 1997. Detecting critical scales in fragmented landscapes. Conservation Ecology 1: 4.

Miller, G. S. 1989. Dispersal of juvenile northern spotted owls in western Oregon. M.S. Thesis. Oregon State University. Corvallis, OR.

Miller et al. 1997. Habitat selection by spotted owls during natal dispersal in western Oregon. Journal of Wildlife Management 61:140-150.

Moilanen, A., and M. Nieminen. 2002. Simple connectivity measures in spatial ecology. Ecology 83: 1131-1145.

O'Brien, D., M. Manseau, A. Fall, and M.-J. Fortin. 2006. Testing the importance of spatial configuration for woodland caribou: An application of graph theory. Biological Conservation 130: 70-83.

O'Neil et al. 2002. Interagency Vegetation Mapping Project (IVMP). Western Washington CascadesProvince Version 2.0. 37 p. January 2002. http://www.or.blm.gov/gis/projects/vegetation/ivmp/province_data.asp?id=3

Pascal-Hortal, L. and S. Saura. 2006. Comparison and development of new graph-based landscape connectivity indices: towards the prioritization of habitat patches and corridors for conservation. Landscape Ecology 21: 959-967.

Ritters, K.H., R.V. O'Neill, C.T. Hunsaker, J.D. Wickham, D.H. Yankee, S.P. Timmins, K.B. Jones and B.L. Jackson. 1995. A factor analysis of landscape pattern and structure metrics. Landscape Ecology 10: 23–39.

Rothley, K.D., and C. Rae. 2005. Working backwards to move forwards: Graph-basedconnectivity metrics for reserve network selection. Environmental Modeling and Assessment 10: 107-113.

Singleton, P.H.; Gaines, W.L.; Lehmkuhl, J.F. 2002. Landscape permeability for large carnivores in Washington: a geographic information system weighted-distance and least-cost corridor assessment . Res. Pap. PNW-RP-549. Portland, OR: U.S.Department of Agricuture, Forest Service, Pacific Northwest Research Station. 89 p. http://www.treesearch.fs.fed.us/pubs/5093

Sutherland, G.D., D.T. O'Brien, S.A. Fall, F.L. Waterhouse, A.S. Harestad, and J.B. Buchanan (editors). 2007. A framework to support landscape analyses of habitat supply and effects on populations of forest-dwelling species: a case study based on the Northern Spotted Owl. B.C. Min. For. Range, Res. Br., Victoria, B.C. Tech. Rep. 038. http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr038.htm

Taylor, P.D., L. Fahrig, K. Henein, and G. Merriam. 1993. Connectivity is a vital element of landscape structure. Oikos 68: 571-573.

Theobald, D. M. 2002. Modeling Functional Landscape Connectivity. ESRI User Conference Proceedings 2002. http://gis.esri.com/library/userconf/proc02/pap1109/P1109.HTM

Theobald, D. M. 2006. Exploring the functional connectivity of landscapes using landscape networks. Pages 416–444 in K. R. Crooks and M. Sanjayan, editors. Connectivity conservation. Cambridge University Press, Cambridge, United Kingdom.

Theobald, D.M., J.B. Norman, M.R. Sherburne. 2006. FunConn v1 User's Manual: ArcGIS tools for Functional Connectivity Modeling. Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO.

Tischendorf, L. and L. Fahrig. 2000. On the usage and measurement of landscape connectivity. Oikos 90:7-19.

Weyerhaeuser Company. 1996. Multispecies habitat conservation plan for the Willamette Timberlands. Benton, Douglas, Land, and Linn counties, Oregon. Weyerhaeuser Company, Springfield OR.

With, K.A., R.H. Gardner, and M.G. Turner. 1997. Landscape connectivity and population distributions in heterogeneous environments. Oikos 78: 151-169.

Urban, D., and T. Keitt. 2001. Landscape connectivity: a graph-theoretic perspective. Ecology 82: 1205-18.

Urban, D.L. 2005. Modeling ecological processes across scales. Ecology 86(8): 1996-2006.